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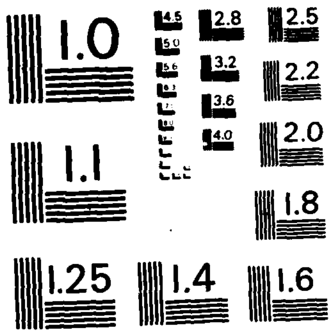
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STOPEM: A SIMULATION INTERDICTION
MODEL OF A MOTORIZED RIFLE
DIVISION

THESIS

AFIT/GST/OS/83M-2 George A. Fulton
Capt USA

AFIT/GST/OS/83M-2

STOPEM: A SIMULATION INTERDICTION MODEL OF A MOTORIZED RIFLE DIVISION

THESIS

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George A. Fulton

Captain USA

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Second-echelon interdiction is closely tied to the close-in battle. In reality, it is part of the integrated battle which says that all means are used to fight the battle at all distances. The objective of this research effort was to examine what effect the combination of air sorties and Army missiles would have against a motorized rifle division (MRD) moving on a hypothesized three-route march. A portion of a selected East German road

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network was chosen as the hypothesized area through which an MRD would be traveling on its way to a release point.

A model of a MRD broken down into 44 units was constructed using SLAM computer simulation language. Units were broken down to battalion size, with a few exceptions. A flight of two aircraft is used to interdict the road on which convoys are traveling. Once a convoy is blocked by the air strike, a retargeting is conducted against the convoy using a generic Army missile loaded with wide-area anti-armor munitions (WAAM). Both the sortie interdiction and missile attack were modeled explicitly using Monte Carlo simulation.

Preface

The successful interdiction of second-echelon forces is inextricably tied to the close-in battle and it is also a problem that overlaps into the joint service arena. Today's weapon systems and the introduction of new systems developed to capitalize on interdiction missions make it more likely that U.S. forces will prevail over any aggressor. As an infantry officer, the author was interested in providing an evaluation of how the combination of air sorties and Army missiles might influence movement of a motorized rifle division on a hypothesized three-route march.

The author wishes to gratefully acknowledge the assistance and the efforts of many people who made this work possible: Major Don Medrow, and others, from Fort Sill, Oklahoma, Corps Support Weapon System Office, for their interest and support; Mr. James N. Rogers and fellow workers at Sandia National Laboratory, Livermore, California, for their ideas and data; Major Roy J. Bogusch, fellow student, who provided insights about the Air Force way of doing things and the use of SLAM; and my thesis committee of Lieutenant Colonel Thomas D. Clark, Jr., thesis advisor, and Lieutenant Colonel Ivy D. Cook, Jr., reader, for providing insights and assistance when the going got tough.

Finally, I wish to thank my wife, Gail Fulton, and my children, Melissa, Emily, and Andrew, for their patience

and understanding throughout the long hours spent on this project and school. This is dedicated to all of you.

George A. Fulton

Contents

List of Figures

List of Tables

Abstract

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STOPEM: A SIMULATION INTERDICTION MODEL
OF A MOTORIZED RIFLE DIVISION

I Introduction

A topic of general interest that has sparked much attention recently is the outcome of a possible general war in Europe. Since the United States maintains its largest military contingent outside its continental borders as part of its commitment to NATO, the possibility exists for a military confrontation between NATO and the Warsaw Pact that would involve the two superpowers. While a general war brings visions of worldwide destruction involving the nuclear arsenals of both superpowers, one scenario would keep the conflict at a conventional level within NATO.

The system of war, with its many interactions, has three escalatory levels above conventional war: (1) chemical-biological (C-B), (2) tactical nuclear, and (3) strategic nuclear. While no one can predict when and how C-B or nuclear weapons would be used, the rational person would argue that use of these weapons would probably be preempted by use of conventional weapons to decide a conflict or conventional superiority could force negotiations. As part of this same rationale, the fact that both sides possess one or both capabilities would be a deterrent for either side to employ them first. Understanding the Warsaw Pact's conventional forces' vulnerabilities and weaknesses within this system context is essential to stopping them conventionally so that the next threshold of war is not breached. Although this is one possible scenario, another one in the literature, "A Selective Nuclear Policy Strategy in Europe: A Selective Targeting Doctrine?", mentions the use of Warsaw Pact selective targeting through use of chemical and/or nuclear munitions to facilitate capturing Europe relatively intact, since their conventional forces are equipped to operate in a chemical or nuclear environment (Ref 19).

While little is openly published about Soviet doctrine, The Offense (A Soviet View) discusses employment of nuclear weapons as an extension of firepower combined with maneuver (Ref 53:v,vii-viii). Because of this lack of information, little is known about Warsaw Pact doctrine. On the other hand, more is being written in U.S. military journals about targeting and employment of nuclear weapons to interdict enemy forces while they are deep in their territory (Ref 30:2-6, 33:2, 57:35). While the Soviet's military force is capable of overwhelming conventionally any adversary, with the added capability for employment and operation in a C-B and nuclear environment, the U.S. has responded to this threat with increased technological enhancements in equipment and weapons and with more of a willingness to possibly use nuclear weapons to offset the numerical Soviet advantage. The clear danger exists that if a conflict starts conventionally, the side that is frustrated first or feels that it is losing the initiative might escalate into the next level of war. Once the war escalates into the nuclear environment, the costs to both sides might far outweigh the gains.

Within the last 10 years, the U.S. Army has examined how to fight the next war. This examination has stemmed from the misunderstanding of Field Manual (FM) 100-5, published in 1976, to its rewriting in 1982. The many articles published in military journals have had a great influence on the revision of this key FM. The study of adversaries' weaknesses and strengths, and the questioning of U.S. doctrine, must continue if the Army and Air Force expect to be ready to fight and win any future conflict. Because of the introduction of many new weapon systems now and in the near future (see Figure 1.1), Army commanders will have at their disposal the means to see and attack deep on the battlefield. Systems such as the corps support weapon system (CSWS), ground-launched cruise missile (GLCM), multiple launch rocket system (MLRS), and family of scatterable mines (FASCAM) give the commander a capability to attack near and far targets. Other systems such as all-source analysis system (ASAS), tactical satellite (TACSAT), stand-off target acquisition system (SOTAS), and tactical fire direction (TACFIRE) provide the detection means and the integration capability for employment of all weapon systems. Having the weapons without the means to effectively employ them reduces their worth. Combined, all systems in Figure 1.1 present a formidable capability. However, owing to war's complexities, a need exists to examine how these numerous systems will interact and how they will damage or delay attacking forces.

Figure 1.2 is a graphical representation of the Warsaw Pact second-echelon threat. As the figure shows, the enemy units are deployed to achieve depth and dispersion. Not only is the bunching of units prevented, but the majority of the forces are uncommitted to exploit success or reinforce other enemy formations. The echelonment of forces is an exploitable weakness upon which NATO must capitalize if the likelihood of victory on the battlefield is to be increased. While "echelonment is neither axiomatic nor uniform," this thesis assumes an attack on NATO would use the idea of echelonment (Ref 4:40). General Starry, former Training and Doctrine Commander (TRADOC), keyed on the importance of echelonment of forces. He stated that the Warsaw Pact keeping a significant portion of its forces uncommitted allowed it to retain the advantage of the initiative to commit at its choosing either to reinforce success or to bypass friendly forces. Furthermore, to upset the Warsaw Pact plan, this initiative must be taken away from the Warsaw Pact and then retained by NATO to gain victory (Ref 57:34).

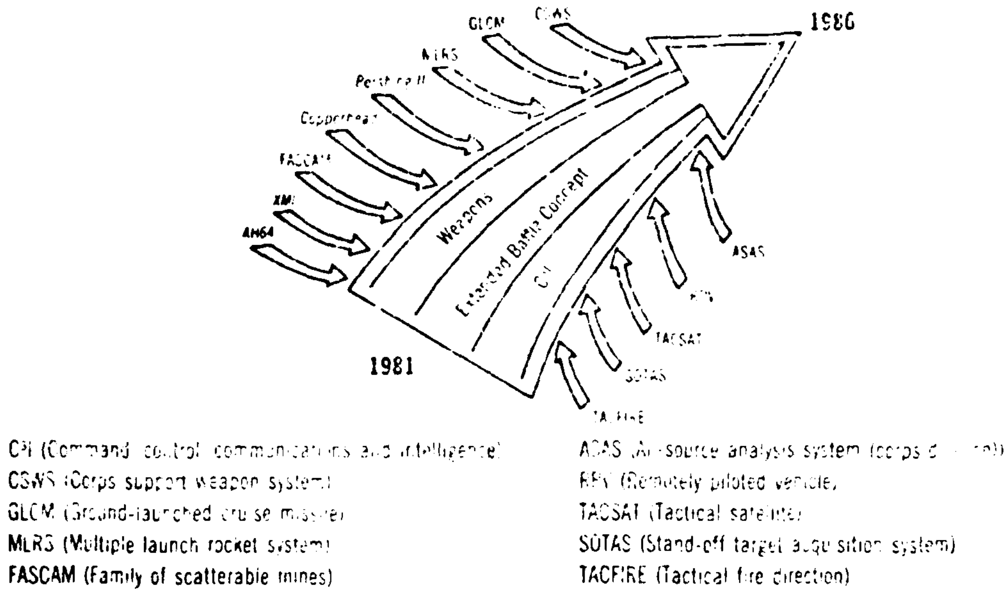


Fig 1.1. A Substantial Step Toward Future Capabilities (Ref 57:33)

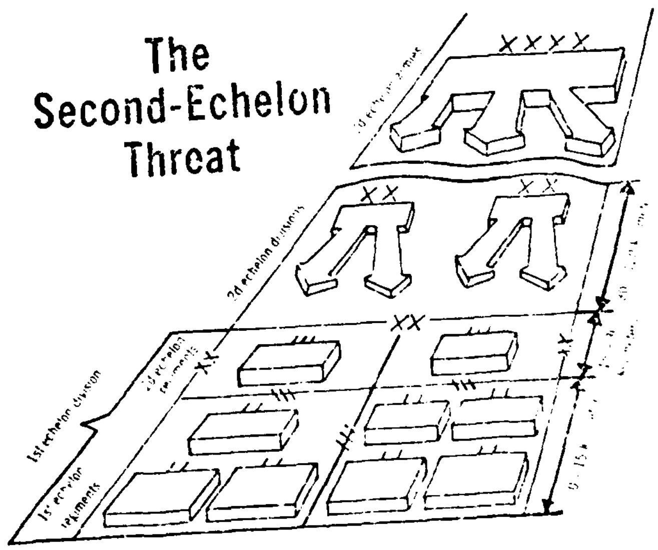


Fig 1.2. The Second-Echelon Threat (Ref 57:35)

A simulation model of second-echelon interdiction would give some insights about interdiction capability as well as providing possible answers to how long enemy forces could be kept out of a sector and what their combat power would be upon their arrival at the point of commitment. A simulation model of interdiction of second-echelon forces would give policy makers an evaluation tool to determine where possible conventional interdiction shortfalls might exist. An analytic approach to addressing this problem was not considered because the system being examined is large, complex, and stochastic. Thus, simulation can best be employed to provide insights to this particular problem. Having a credible, conventional interdiction capability should lower the U.S. nuclear response. However, the uncertainty of the Warsaw Pact initial response, or its response if thwarted in any attack, still remains.

Problem Statement

What is the structure of the interdiction subsystem contained within the overall system of conventional war, how can this particular subsystem be captured in a dynamic model, and how can this model be used to evaluate specific policies? More specifically:

1. What are the significant relationships in Corps-directed aircraft sortie interdiction of terrain-restricted roads and the effects on second-echelon forces moving through the road network interdicted?

2. How would a relook capability that enables retargeting of the interdicted point with missiles loaded with wide area anti-armor munitions (WAAM) reduce the combat power of delayed units or increase their delay time?

3. How can these relationships be incorporated into a model that will enable military planners to evaluate capabilities and effectiveness of selected conventional munitions against second-echelon threats?

Objectives

The primary objective of this research is to provide a validated model of interdicting a selected road network in East Germany to gain insights into how long a Warsaw Pact motorized rifle division (MRD) could be delayed from being committed into a corps sector and what its combat power would be upon reaching its destination. Intermediate objectives are:

1. Develop a basic model containing a typical MRD broken into battalion-size units making a 100 kilometer (Km) road march on three separate routes.

2. Add an interdiction scheme that shows how these effects alter the MRD's arrival and combat power, where combat power refers to its main fighting systems (armor, infantry, artillery).

3. Verify and validate the model.

4. Use the model to evaluate effects of aircraft and missile sortie allocation on the MRD.

System Structure

This research is directed at understanding and modeling the flow of convoys through a road network and how to impede their flow so that their arrival into a corps sector would either be delayed for a short time with high losses, be delayed for a long time with low losses, be delayed for a long time with high losses, or not be affected at all. The ideas above represent four possible enemy force statuses of combat capability. For example, if a force could not be delayed out of sector for as long as a pre-specified time, say 12 hours, then a possible acceptable alternative might be to keep it out less time, but with a reduced percentage of combat vehicles, such as tanks, infantry, and artillery, by diverting more assets to interdiction. To achieve such goals requires that all resources be effectively integrated on any future battlefield so that the likelihood of success is increased.

Background

To set the problem in perspective, a description of the integrated battlefield is given first. A corps sector is described and an explanation of how the Corps commander views the battlefield is given. Also, the conduct of the integrated battle is described along with how deep attack affects enemy force arrivals at the forward line of own troops (FLOT). Next, an examination is made of the last decade's questions about Army doctrine. Specifically, the debate is traced that questions how the Army will fight the next war and what the implications are of the active defense.

System Description. Figure 1.3 is a causal loop diagram that depicts the complex interactions of deep attack. Such diagrams are used in system analysis as tools to graphically represent and to aid in visualization of the system structure and key relationships. Feedback between or among relationships denotes that one relationship can influence another. However, even when relationships do exist, feedback may not exist. Connections between variables are depicted as solid lines with an arrow-tipped end that either has a positive or a negative sign. A positive sign indicates that an increase in one variable will result in an increase of another variable in the same loop. A minus sign denotes that increasing one variable will decrease the other one at the arrow tip. By multiplying all the signs within a loop, a net sign is obtained. A positive net sign indicates a positive or reinforcing loop. An outside type of control prevents a continued increase of relationships when acted upon by some external influence. The relationships within the loop continue increasing unless restrained by this external factor. On the other hand, a negative or goal-seeking loop tends toward equilibrium or a balance when acted upon by an outside element. The net effect of this process is that causal loop diagrams aid the models during

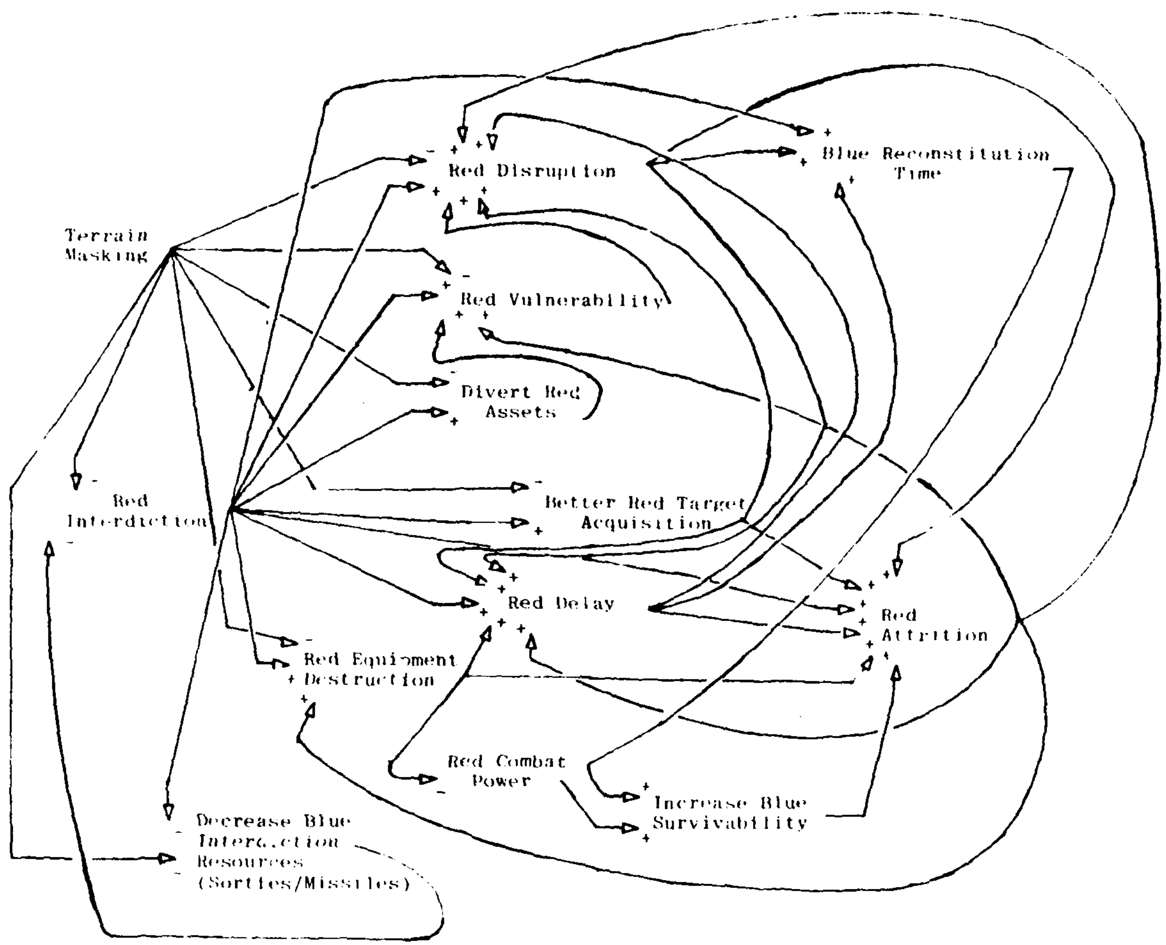


Fig 1.3. Causal Loop Diagram (Ref 65)

the development phase by assisting in conceptualizing and formulating key relationships. Thus, a better system understanding is the result.

Figure 1.3 shows part of the complexities associated with deep attack. As the figure shows, interdiction of red forces decreases blue's interdiction resources, but increases red equipment destruction, red delay, red target acquisition, diversion of red assets, red vulnerability, red attrition, and blue's reconstitution time. As the figure also shows, these same variables affect other variables within the loop. For example, attrition can have an affect on destruction, delay, or disruption. But, destruction, delay, or disruption also affect red attrition because as convoy elements are destroyed, delayed, or disrupted on their routes of march, they present better targets. This bunching of vehicles on the roadway increases red's vulnerability as well as facilitating acquisition. One fallacy with stating that target acquisition is always improved is that terrain masking may make it more difficult to detect targets. So in actuality, target acquisition and other variables could be decreased due to an inability to see targets. This is a function of such variables as terrain, degree of cover, time of the year, weather, and detection equipment.

A portion of a corps sector was selected for this problem as being the area where an MRD would penetrate the sector and become the concern of the commander. Also, this same sector is part of an overall area of interest being examined to provide insights to the CSWS office, Fort Sill, Oklahoma. Figure 1.4 shows the whole corps sector organization. A brief explanation follows of the key elements on the figure as well as tying them to the concept of the extended battlefield.

Briefly stated, the extended battlefield idea is a more descriptive term that captures how to view the battlefield in terms of time, space, enemy forces, friendly forces, and weapons employment. Enemy forces are to be engaged while not in contact to frustrate their command and control, and to strip away their initiative. Secondly, all current actions are interrelated in time in that plans for the close-in battle as well as attack of follow-on forces are tied to winning at the FLOT. Finally, the integrated assets of "higher level Army and sister services" are carefully employed in interdicting the battlefield (Ref 57:32). The key point is to carefully employ all assets and resources so that interdicting deep targets is tied to the close-in battle.

As enemy forces penetrate the corps sector and are located about 96 hours out from the FLOT, they are within the corps area of interest. Within this area the commander must monitor enemy movement so that he can determine what

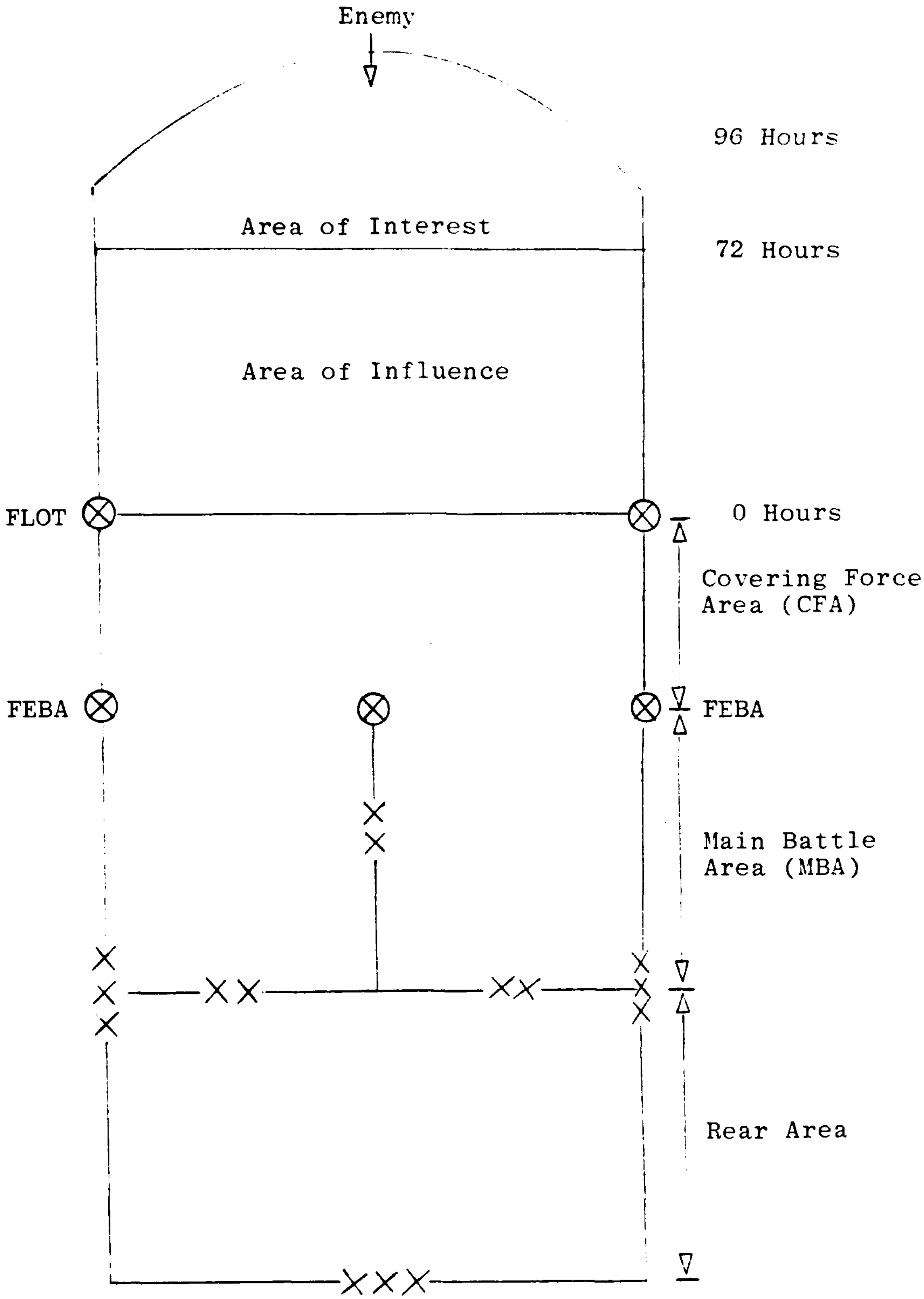


Fig 1.4. Organization of the Defense - Corps

forces could affect his future operations. The decision to interdict is made here.

Closer in exists the area of influence where the commander is also capable of acquiring the fighting enemy units with assets organic to or in support of his command. For instance, a division may be maneuvering units against the second-echelon regiments of the first-echelon division. In order to increase the chances of success against the enemy forces and prevent their being reinforced by second-echelon divisions, the second-echelon divisions would have to be destroyed, delayed, or disrupted for a prespecified period of time and/or decreased level of combat power. This is an area where intelligence estimates and advance planning would pay off. Tables 1.1 and 1.2 show areas of influence and interest as functions of level of command and time distance from the FLOT in hours.

TABLE 1.1

Areas of Influence

Level of Command	Distance from FLOT (time in hours)
Brigade	0 to 12
Division	0 to 24
Corps	0 to 72

(Ref 16:53)

TABLE 1.2

Areas of Interest

Level of Command	Distance from FLOT (time in hours)
Brigade	0 to 24
Division	0 to 72
Corps	0 to 96

(Ref 16:53)

The remainder of Figure 1.4 depicts the location of friendly forces. The point where the forwardmost friendly elements, the covering force, are located is defined as the FLOT. From the FLOT back to the forward edge of the battle area (FEBA) is designated the covering force area (CFA) where the corps covering force (CF) will provide early warning to the forces in the main battle area (MBA) about the enemy's intent and direction of main attack, "to develop the situation, and to delay or defeat the enemy's leading fighting force" (Ref 30:10-8). As the battle develops in the CFA, commanders make final preparations in the MBA. Also, as the CF fights back to the MBA, the CF hands the enemy over to the forces in the MBA, where the majority of the fighting is anticipated as taking place. Consequently, it is in the MBA where the majority of friendly units are located. Finally, the rear area is to the immediate rear of the rear boundary of the MBA, where command and control elements, reserve, and support units are located. This quick, simplified description of how a corps sector is organized, is more complicated than explained. However, the points covered are the highlights.

As Figure 1.5 shows, the advancing enemy force moving in is detected and engaged in the area of interest. Within this area, the enemy forces are subjected to attack by all available resources. The result of continued interdiction all along its movement path toward the FLOT combined with maneuver create the result in Figure 1.6. Finally, Figure 1.7 shows the reconstituted FEBA, after destruction of the first-echelon forces. The reconstituted FEBA is better prepared to engage the new units entering or that have entered corps sector.

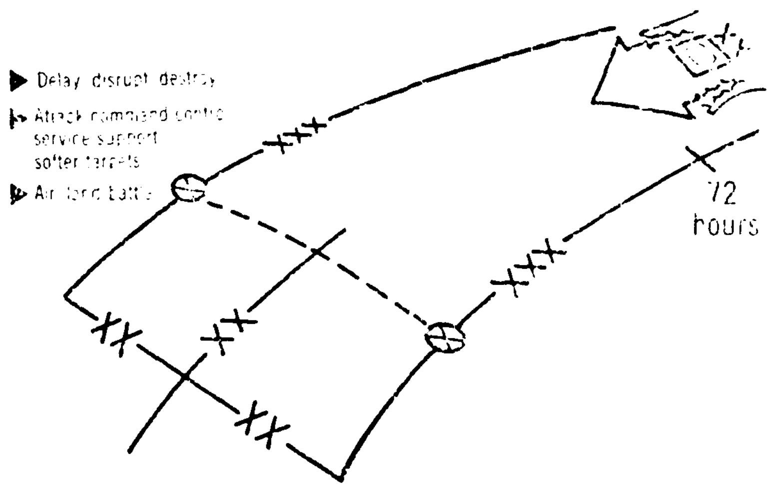


Fig 1.5. The Deep Battle (Ref 57:39)

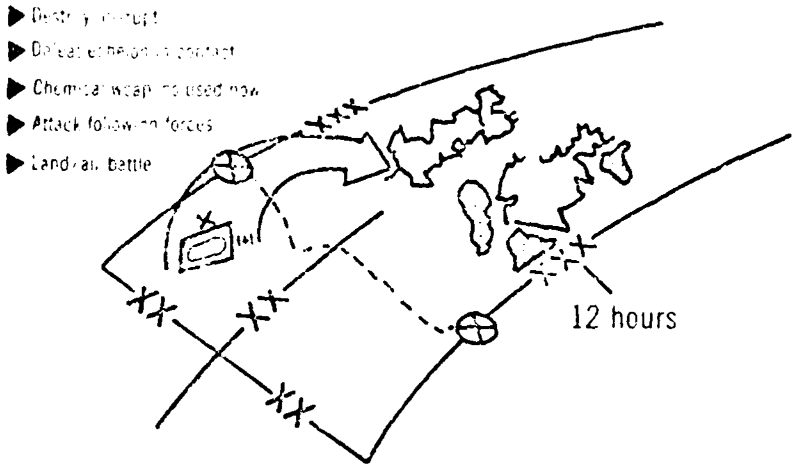


Fig 1.6. The Integrated Battle
(Ref 57.42)

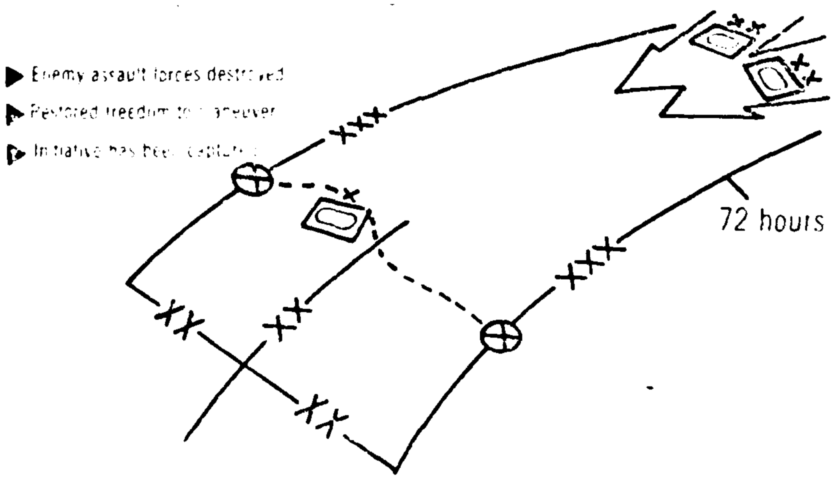


Fig 1.7. The Outcome (Ref 57:43)

A plot of this effect of interdiction is shown in Figure 1.8. The upper portion of the plot of enemy front-line strength against time shows that no interdiction allows the enemy forces to maintain a fairly constant density of forces at the FLOT. This translates to more combat power to maintain the initiative and to overwhelm the friendly force. The bottom curve shows the effect of interdiction and attack. As interdiction destroys, delays, or disrupts enemy forces, windows for action are created where a time period exists that friendly-to-enemy force ratios are favorable to attack. It is within these windows created by interdicting that maneuver and firepower will produce destruction of enemy forces. This curve shows why it is absolutely necessary to destroy, delay, or disrupt any enemy forces that could interrupt the maneuvering friendly units before they get to finish their destruction mission. The results from the figure were generated from simulation comparisons conducted by the Army's Field Artillery School, Fort Sill, Oklahoma, of 1980 European corps battles (Ref 57:42).

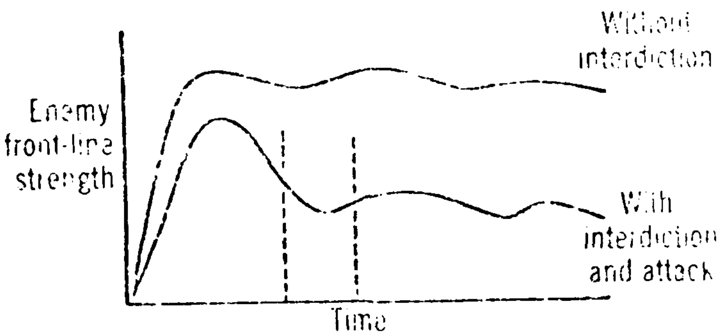


Fig 1.8. Why Deep Attack? (Ref 57:45)

Doctrinal Refinement. Two discernible periods of Army doctrine refinement can be traced from the writing of FM 100-5 in 1976, to the time between its initial publication and its republication in 1982. The original FM version was "notably flexible and deliberately nonrestrictive" (Ref 60:3). The active defense called for lateral movement along the FEBA to achieve concentration of forces at the threatened point. Depth on the battlefield was achieved by a series of delaying actions conducted all the way back to the rear boundary. These actions were the maneuvers associated with the active defense. Offensive action was interpreted to be practically nonexistent. At the rear boundary, the defense ended up being linear. "It was this rigidly limited form of defense which attracted most of the attention of critics and prompted the long series of debates which still goes on." (Ref 60:3,4) Colonel Tate and Lieutenant Colonel Holder in their article, "New Doctrine for the Defense," went on to say that the doctrine in the FM 100-5 was interpreted to be dogmatic, when in fact it was supposed to be flexible and nonrestrictive. Hence, the ensuing debate and the eventual rewriting of this manual.

The author's perception is that a critical transition occurred with an enlightening article written by Colonel Wagner, "Active Defense and All That." Colonel Wagner gave his astute conceptualization of how the active defense was to be fought. Using his command, the 11th Armored Cavalry

Regiment, as an example, he reintroduced offense into the active defense. Through his example, he described his command performing a covering force mission using all available assets, terrain, and maneuver to defeat an attacking force (Ref 63). The scenario and tactics he described represent the essence of the active defense. This particular article did more to crystalize the flexibility and intent of active defense than any other article up to that point.

The article by General Starry, former TRADOC commander, entitled, "Extending the Battlefield," was a benchmark in further clarifying the integration of all assets and thought to the complete depth of the battlefield. Commanders and staff had to view the battlefield as closely interrelated parts of the close-in battle and deep battle. This careful integration of all assets in fighting the extended battlefield reminded all commanders that success in the close-in battle was tied to the deep one (Ref 57).

Other journal articles before and since the Wagner and Starry articles also deserve some brief comment to reflect the breadth and intensity of attempting to clarify doctrine and, in some cases, introducing innovative ideas. Articles such as Brittingham's, "Use the Lightning," describe an expanded role for attack helicopters to capitalize on their potency as very mobile anti-armor forces. The mobility and flexibility in this weapon system gives the commander an excellent counter penetration force. Other ideas include doctrinal questions previously discussed as well as articles by some Air Force authors from defining the mission of battlefield air interdiction (BAI) to the effects of European weather on round-the-clock air operations. In True's article, "The Tourniquet and The Hammer," the author suggests in his title the analogy of deep interdiction using two historical raids on the Romanian oilfields at Ploesti (Ref 62). Frizzo writes about some unique ideas in the rapid deployment of U.S.-based forces to Europe being used as infantry reinforced with an anti-tank capability. These forces represent mechanized units or light infantry units deployed without heavy equipment to be employed against the second echelon forces (Ref 22). Porreca advocated a rethinking of tactics to use the indirect approach as espoused by B. H. Liddell Hart. One of his major points is that military school students have become so enamored of the most current terminology to describe current doctrine that they are just parroting the party line without offering any new insights (Ref 48). An examination of the bibliography gives an indication of some of the professional thought that has served to enlighten, to question, to analyze, and to present ideas that are relevant to this crucial issue. This brief excursion plus the synopsis of the following studies will serve to illustrate the intensity and concern being shown by military professionals and others in both branches of the service and outside agencies.

Air-Land Forces Application (ALFA) Agency, headquartered at Langley Air Force Base, Virginia, is a joint service organization examining the problems associated with conduct of the deep battle. Since the Air Force possesses more assets to conduct deep interdiction, to include second echelon forces, both the Army and Air Force have had to reexamine the doctrine of interdiction beyond the FLOT in the Army's defined areas of interest and influence. Traditionally, the Air Force had had almost exclusive say in what was interdicted beyond a certain point in the battlefield. But, now Army commanders want a bigger input in influencing action in what has been traditionally an Air Force domain because affecting the arrival of echeloned forces has a direct impact on maneuver schemes in the close-in battle. Since both services are working toward the same end, it is desirable that better cooperation and compatible doctrine exist between the services in order to purposefully employ limited assets to get the greatest effect.

Two Army agencies that are also examining the problem of second echelon interdiction are located at Fort Sill, Oklahoma, and Fort Leavenworth, Kansas. Fort Sill is the home of the Corps Support Weapon Systems (CSWS), a Department of the Army task force. The group there is working with Sandia National Laboratory and their network interdiction model to evaluate nuclear strikes targeted against follow-on forces. The model is a computerized simulation that depicts real time movement of two Soviet divisions moving on two routes from assembly areas into their objective areas. The personnel working on the model are still adding refinements to the model that will capture all the effects of strikes of this nature. This work is ongoing at Sandia National Laboratory, Livermore, California (Ref 14).

The Fort Leavenworth group, The Combined Arms Combat Development Activity (TCADA) (Ref 42), is examining how revived offensive capability in the form of maneuver is affecting outcomes in the close-in battle. The ideas being examined are similar to the ones put forth by Wagner in his articles on the active defense. Results of these studies stress the creation of lighter and more mobile units with the capability to fight in a very dynamic battlefield environment.

The level of interest in this second echelon interdiction problem extends to other agencies, student thesis efforts, and numerous interesting articles in professional journals. The DCUBE Model (Destroy, Disrupt, and Delay), an Air Force analytical model developed for it by A. T. Kearney, Inc., evaluates mobility disruption by air strikes by both Blue and Red air forces against the opposing side's ground forces. The model uses an Arrival Rate (AR) sub-model to determine force arrival rates at the FLOT. These results are then fed into the Ground Battle (GB) sub-model, which uses a modified Lanchester Square Law in its simulation.

The model's measure of effectiveness (MOE) is battle outcome. Parametric studies were conducted to determine the model's sensitivity to weather effects and force variations. Plots against time were then made that show the arrival of reinforcements and combat forces remaining on the battlefield for these parametric variations (Ref 59). These model outputs verify the same results the Fort Sill study obtained in Figure 1.8. "A Simulation of Second Echelon Air Interdiction" is an AFIT student's thesis attempt at correcting weakness in the DCUBE model to develop his own air interdiction model. Bennett identified weaknesses, such as constant number of attacking aircraft, no incorporation of variance, and constant kill rates for airplanes and trucks (Ref 59), that he thought should be corrected by his formulation in an attempt to get a better representation of interdiction. His thesis compares his model's arrival rate output against results of the DCUBE model to arrive at similar conclusions. Identified weaknesses in Bennett's effort include the following: the second echelon forces were modeled as trucks only and many replications are needed to get results (Ref 5).

Dees' thesis (Ref 17) gives a good background discussion on second echelon interdiction, how similar problems are being examined in the Army community, and on his recommendation to apply Queueing-Graphical Evaluation and Review Technique (Q-GERT) in the development of his proposed

Model Q-STAR (Queueing supplement to STAR (Simulation of Tactical Alternative Responses) combat model). He stresses the utility of how Q-GERT can be readily used to model second echelon forces in Q-STAR. This thesis sets a foundation for later development of Q-STAR (Ref 17).

Interdiction Planning is an unpublished paper obtained from Major Starner, formerly of CSWS at Fort Sill. This source discusses a general approach to interdiction planning and then applies this methodology to a particular sector in Germany. This article reinforces General Starry's message of practicing interdiction planning now with current resources so that expertise is developed at all levels. Targeting is examined for both division and corps levels (Ref 54).

An examination of the remainder of the bibliographical references shows other articles, books, and studies on work done by both Army and Air Force personnel. Included are also works by other governmental agencies or contractors. The level of interest displayed is indicative of the importance attached to the particular problem of second echelon interdiction.

Methodology

A systems approach was the methodology applied in this research effort. Since the subsystem described previously is part of a large and more complex system, a systems approach can best be used for this policy analysis because it aids in understanding the system more fully.

The Systems Approach. By using the process described by Schoderbek, Schoderbek, and Kefalas in Management Systems Conceptual Considerations, a more complete understanding can be gained about that system so that the perceived problem or required policy to be studied can be isolated into its component parts for analysis: "the input(s), the process(es), the output(s), and the feedback control" (Ref 50:14). A mathematical model can then be formulated to represent this isolated part of the system so that an analysis can be made between feedback structures and system components as they interact over time. Once the model is built, studies can be conducted on the model to obtain insights on how changes affect the system or to analyze new problems. The value of this effort does not lie solely in information obtained, but also in gaining insights about the system all during the model development.

Thus, systems analysis can provide a valuable tool in correctly specifying, delimiting, and understanding the problem to be studied prior to time being wasted on answering the wrong question.

Applied Methodology. How system analysis was used in the research phase follows. Since second echelon interdiction is a subsystem of the main system of war, a narrowing of the overall, general system was necessary to isolate key relationships essential to understanding how the subsystem operates and interacts. A cyclic process was used throughout the model development until the model was finally accepted as an accurate system representation of the interdiction process. This iterative process was a constant, ongoing thing to insure system accuracy. Figure 1.9 depicts this process as it relates to the simulation process.

Initial system conceptualization and ideas were obtained on visits to the CSWS office at Fort Sill, Oklahoma, and Sandia National Laboratory at Livermore, California. Further readings and research aided in further understanding the system process. From those efforts, system causal relationships were developed.

A thorough map analysis of a road network in East Germany identified choke points on the routes hypothesized for movement of a motorized rifle division (MRD). From the identified choke points emerged an idea of where to cut the roads with general purpose bombs so that convoy passage would be blocked. The MRD was selected as moving on three separate routes to minimize the convoy length and to represent WP doctrine of maintaining unit dispersal. Unit characteristics, such as number and type of units, types of vehicles, convoy lengths, were obtained from <u>Opposing Forces Europe</u> (Ref 31). The terrain restricted points on the route imply that the terrain restricts the movement of the units to the roadway only because high ground to either side of

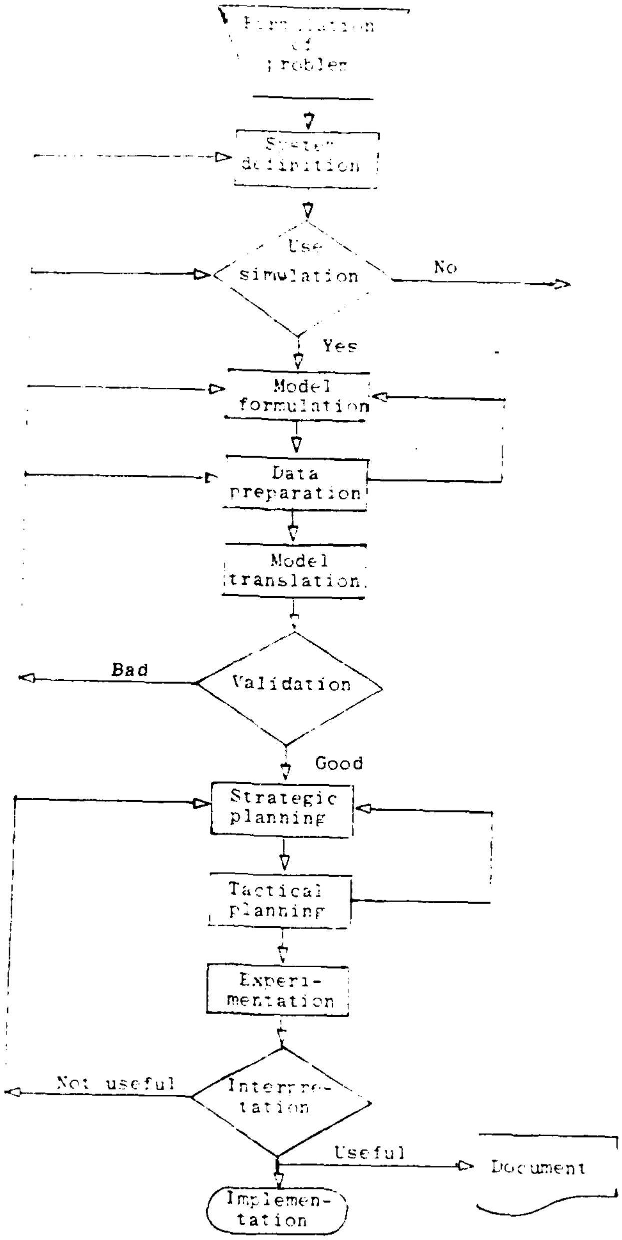


Fig 1.9. Simulation Process (Ref 51:24)

the road does not allow bypass. Also, selecting these restricted points included insuring that no other alternate roads in the immediate area would allow easy routing around the obstacle. Targeting an area other than these points would not impose appreciable delay or create unit bunching because units could bypass the obstacle by going around it either by use of an alternate route that easily puts them back on their original route or by simply going off the road and back on the road again. Once the convoys are blocked, a relook and retargeting capability would allow for retargeting of the area with one or more missiles loaded with wide area antiarmor munitions (WAAMS). This targeting process should tell a commander where to make the necessary cuts so that he can destroy, delay, or disrupt the flow of incoming enemy forces and thereby create a tactical situation that allows for destruction of the first echelon while delaying the arrival of the second echelon. The above implementation is described in subsequent chapters.

Order of Presentation

The next six chapters present the implementation of the research methodology, policy evaluation, and recommendations for further research.

Chapter II is the model Description and Development. Within it, key points discussed include how parameters were developed, what assumptions were used, how the interdiction was formulated, and how all parts of the model were integrated.

The Simulation Model is next in Chapter III. Within this chapter, how the model was computerzied is described.

Validation and Verification, Chapter IV, disucsses the process of verifying the functioning of the model.

Data Collection, Chapter V, discusses experimental design and sample size determination.

Chapter VI presents the data analysis for the experimental design. Finally, Chapter VII presents the Conclusions and Recommendations, and Recommendations for Follow-on Study.

Summary

Presented in Chapter I has been the problem, the research question, a background on research, and the applied methodology for this research project. Chapter II follows with the model.

II System Structure

The model STOPEM was developed to analyze the problem stated in Chapter I. The purpose of this chapter is to present the methodology involved in developing the structure for STOPEM. The main components of this structure are: convoy movement, sortie attack, missile attack, damage assessment, and delay assessment. STOPEM's initial development consisted of modeling the physical convoy movement of the 44 motorized rifle division (MRD) units through three separate routes. Once the physical movement development was completed, the actual interdiction and damage assessment of the convoys were added. This particular method aided in model verification. The following will trace the development of these ideas.

Convoy Movement

Both Opposing Forces Europe (Ref 31) and Soviet Army Operations (Ref 32) were consulted to obtain the necessary information to build this initial portion of the model. Soviet Army contains the basic Soviet Doctrine on convoy movement, convoy intervals, rates, and use of multiple routes to maintain dispersion. Appendix A of Opposing Forces lists descriptions of units from company to Warsaw Pact FRONT, their equipment, and personnel assigned.

From Opposing Forces Europe (Ref 31), a MRD was broken out into 44 different units of approximately battalion size. The exceptions to this breakdown are division headquarters (modeled as two entities--main and alternate, both of equal size), the regimental headquarters (five), three anti-aircraft batteries, a target acquisition battery, and the services-rear security. Table 2.1 shows the breakdown into the various elements, their route designation, and the average length of the convoy. The three anti-aircraft batteries are detached from their regiment unit to provide air defense within the three columns. The only MRD unit not considered in this formulation is the division reconnaissance battalion. This unit is omitted because it would be operating about 50 kilometers in front of the MRD (Ref 32:9-4). Thus, it would not be cost-effective to delay this unit since it could radio back to the main force about blockages ahead and that would allow the MRD an early option to select an alternate route.

Sampling from a triangular distribution is conducted for convoy rate, convoy length, and convoy interval because variables are considered to be stochastic in nature. Since data for these parameters in Soviet Army Operations (Ref 32) is given in minimum and maximum values, a triangular distribution is selected as the sampling distribution because the description of the process and the absence of real data fit the circumstances when this distribution could be used. In

TABLE 2.1

Motorized Rifle Division Units

Unit Number	Description	Route	Average Length (KM)
1	1st MR Regiment Advanced Guard	Blue	3.6
2	1st Regiment HQs.	Blue	1.13
3	Tank Bn (-)	Blue	1.35
4	MR Bn	Blue	1.65
5	MR Bn (-)	Blue	1.5
6	Services - Rear Security	Blue	3.75
7	Tank Bn	Blue	2.1
8	Division HQs (alternate)	Blue	1.31
9	Target Acquisition Battery	Blue	0.6
10	Artillery Bn (152 mm)	Blue	2.4
11	Artillery Bn (122 mm)	Blue	2.4
12	AAA Battery	Blue	0.75
13	Anti - Tank Bn	Blue	2.85
14	FROG Bn	Blue	1.95
15	Transportation Bn	Blue	7.65
16	2nd MR Regiment Advanced Guard	Green	3.6
17	2nd Regiment HQs	Green	1.13
18	Tank Bn (-)	Green	1.35
19	MR Bn	Green	1.65
20	MR Bn (-)	Green	1.2
21	Services - Rear Security	Green	3.75
22	Artillery Bn (122 mm)	Green	2.0
23	Artillery Regiment HQs	Green	2.25
24	AAA Regiment (-)	Green	2.25
25	Engineer Bn	Green	3.75
26	Signal Bn	Green	2.25
27	MLRS Bn	Green	2.7
28	Chemical Bn	Green	1.65
29	Maintenance Bn	Green	2.55
30	AAA Battery	Green	0.75
31	Medical Bn	Green	1.35
32	Tank Regiment Advanced Guard	Red	2.25
33	Tank Regiment HQs	Red	0.75
34	Tank Bn	Red	1.5
35	Tank Bn (-)	Red	1.2

Note: (-) = Unit minus some forces

TABLE 2.1 (Continued)

Unit Number	Description	Route	Average Length (KM)
36	Services - Rear Security	Red	3.9
37	Division HQs (Main)	Red	1.31
38	AAA Battery	Red	0.75
39	3rd MR Regiment Advanced Guard	Red	3.6
40	3rd Regiment HQs	Red	1.13
41	Tank Bn (-)	Red	1.35
42	MR Bn	Red	1.65
43	MR Bn (-)	Red	1.5
44	Services (Div & Reg)-Rear Security	Red	5.55

other words, a triangular distribution "is used when a most liekly value can be ascertained along with minimum and maximum values, and a piece-wise linear density function seems appropriate" (Ref 49:30). The mode for the distribution is calculated as the average of the minimum and maximum values given. Once these three parameters are available, sampling can be conducted. A flexibility of this distribution is its ability to vary the mode to meet changing conditions. For example, the mode for the rate would be expected to decrease over time because of the effects of degradation of road surfaces and interdiction.

Next, the parameters for convoy interval, rate, and length are obtained as follows. The minimum and maximum values for the above parameters are obtained from Soviet Army Operations (Ref 32:3-20,3-21). The interval between all units is taken to be between three and five kilometers, with a mode of four. The exception is the advanced guard element on a route. The interval between it and the main body of the convoy is between 20 and 30 kilometers, with a mode of 25. A mixed convoy rate for daytime conditions is selected because a day road march is assumed. A day road march is assumed due to constant convoy movement forward. The values for the minimum, mode, and maximum are 20, 25, and 30 kilometers per hour, respectively. Minimum and maximum convoy lengths are computed by multiplying the number of vehicles in the convoy (discussed in subsequent paragraph) by the minimum and maximum interval between vehicles

(25 and 50 meters, respectively) plus the minimum and maximum intervals between companies within a battalion (25 and 50 meters, respectively). This method of computation assumes a measurement interval from mid-vehicle to mid-vehicle. Once these minimum and maximum unit lengths are computed, an average value (the mode) is computed. This value appears in Table 2.1 as the average length.

To compute unit minimum and maximum lengths, the number of vehicles in a convoy has to be determined. Opposing Forces Europe has what appears to be an incomplete listing of the number of vehicles under the MRD table (Ref 31:A-12). For example, the engineer battalion has 385 personnel, but only 10 wheeled vehicles to carry these personnel and equipment. This is resolved by going to another page of the same appendix to find the same unit with a complete listing of vehicles. In other cases, units listed do not include any vehicles at all. In these cases, a similar organization found under a separate listing is used as a comparable substitute. For example, the data for the medical battalion was found under divisional services for the MRD. In Figure 2 of Soviet Army Operations, a regimental headquarters is shown being augmented with another unit such as a regimental artillery group. Since this represents a particular attachment for combat and not a general case as this model portrays, regimental headquarters in the model are portrayed without special attachments. Of course, having additional attachments implies that the unit length parameters would increase. What these examples attempt to portray is that exact figures for all units are not available so cross checking made above is used to calculate the number of vehicles. The sources examined represent the most complete unclassified listing available.

All track vehicles (tanks (all types), infantry fighting vehicles (BMP), self-propelled artillery pieces, and engineer vehicles) and all wheeled vehicles (towed artillery pieces, trucks, and reconnaissance vehicles) are grouped into either track or wheeled vehicle categories. Once total number of vehicles per unit is determined, unit length is computed. For example, unit one has 57 track vehicles and 32 wheeled vehicles. Units 1, 16, and 39 are all advanced guard elements for three different motorized rifle regiments. This element is a motorized rifle battalion reinforced with an armor company, a reconnaissance company, mortars, an engineer detachment, an artillery battery and various combat support vehicles. To compute unit minimum, maximum, and average lengths for this unit, the following is done:

$$\begin{aligned} \text{min length} &= (\text{number of vehicles})(\text{minimum interval}) + \\ &\quad\ (\text{number of companies})(\text{minimum interval}) \\ &= (89)(25) + (6)(25) \\ &= 2375 \text{ meters} \\ &= 2.375 \approx 2.4 \text{ kilometers} \end{aligned}$$

$$\text{max length} = (\text{number of vehicles})(\text{maximum interval}) + (\text{number of companies})(\text{maximum interval})$$

$$= (89)(50) + (6)(50)$$

$$= 4750 \text{ meters}$$

$$= 4.75 \approx 4.8 \text{ kilometers}$$

$$\text{average unit length} = \frac{\text{minimum length} + \text{maximum length}}{2}$$

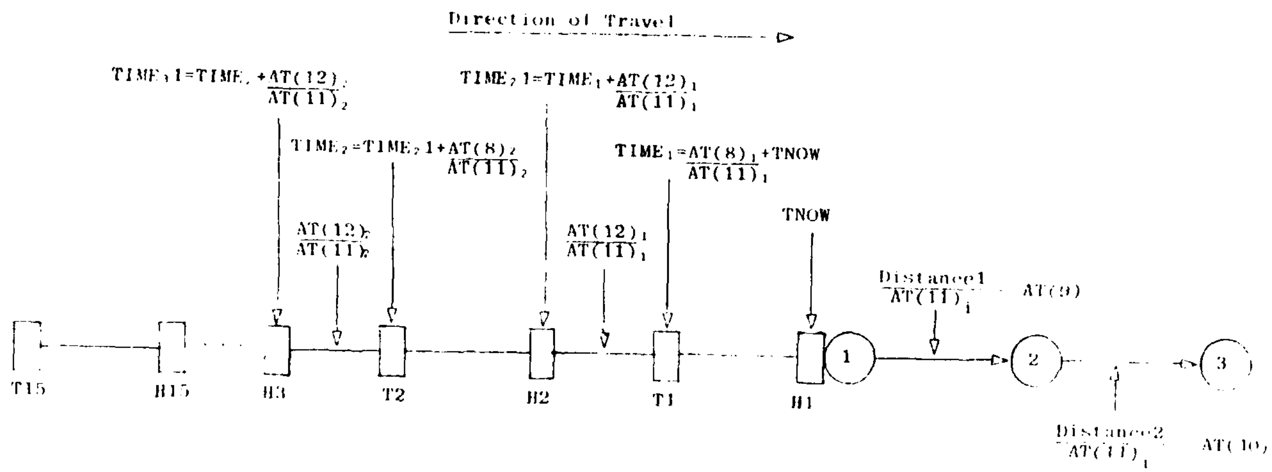
$$= \frac{2.4 + 4.8}{2}$$

$$= 3.6 \text{ kilometers}$$

A similar calculation is done for all other units. Once all intervals are calculated, convoy number plus values for number of track and wheeled vehicles, unit lengths, and unit rate characterize each convoy entity.

Convoy order on each route is established with an advanced guard element at the head, with the remainder of each regiment and other units behind it. The division main and alternate headquarters are placed on separate routes for redundancy. Combat service support elements are placed to the rear of columns, and the main combat elements and their controlling headquarters are placed toward the head of each column.

Figure 2.1 is a static depiction of how convoy movement is modeled and Figure 2.2 is a simplified road network depiction. As mentioned earlier, this model assumes a hypothesized three route move for a MRD. Figure 2.2 shows the representation of the main route for each convoy. The



where: ATRIB(8)	=	Sample from triangular distribution for convoy length (km)
ATRIB(11)	=	Sample from triangular distribution for day march rate (km/Hr)
ATRIB(12)	=	Sample from triangular distribution for interval distance (km)
H1	=	Head vehicle of convoy 1
T1	=	Tail vehicle of convoy 1
H2	=	Head vehicle of convoy 2
T2	=	Tail vehicle of convoy 2
H3	=	Head vehicle of convoy 3
:		
H15	=	Head vehicle of convoy 15
T15	=	Tail vehicle of convoy 15

Fig 2.1. Static Depiction of Convoy Movement, Route BLUE

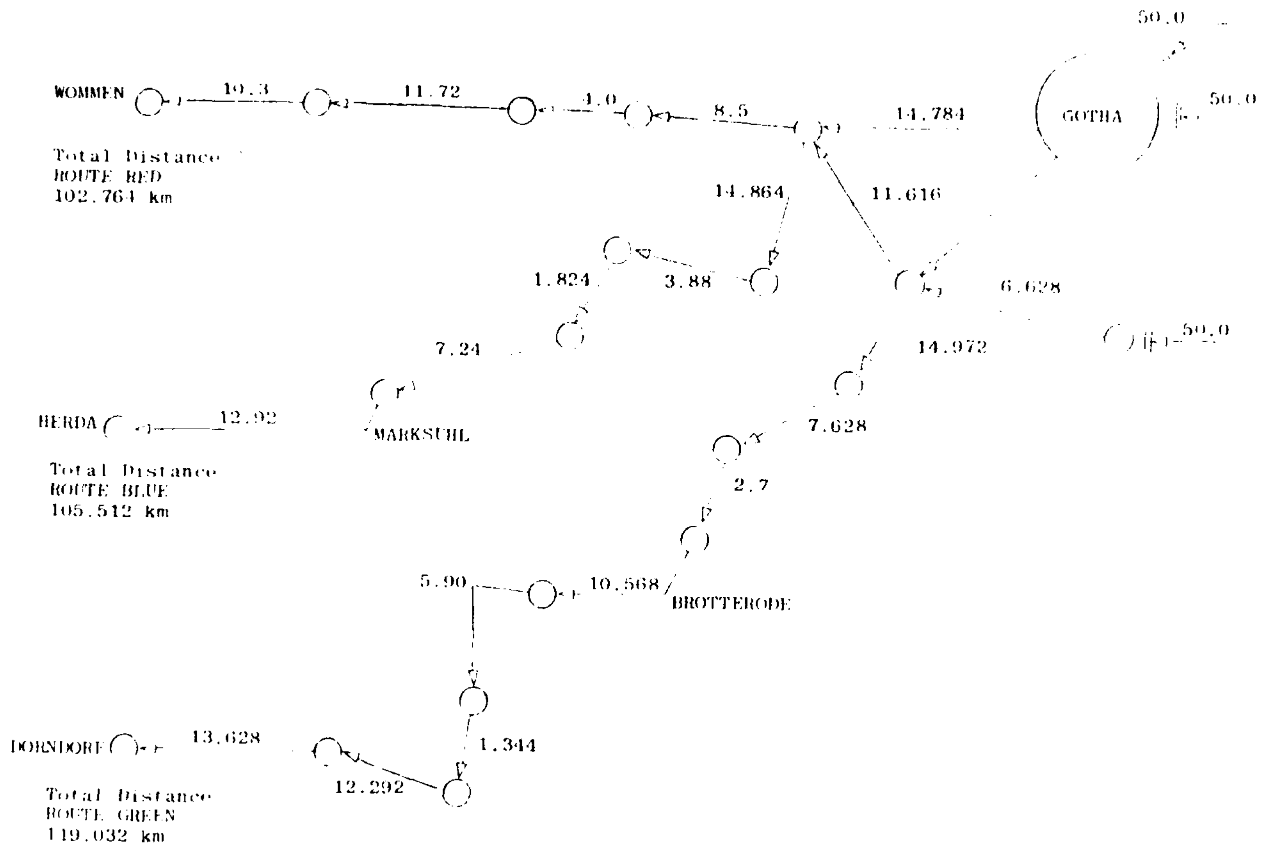


Fig 2.2. Road Network

numbers between nodes (circles) represent the distance in kilometers between these points. Convoys are assumed to have been moving for 50 kilometers prior to entering the road network of interest. These values were obtained on a visit to Sandia National Laboratory and at random verified using manual plotting on a military map of the area in Germany. This is a simplified network because the extremely complex road network available (other roads and forest trails) is not shown. Since this model assumes a hypothesized travel route based on Warsaw Pact doctrine, these routes are selected to approximate where convoys might actually travel. Based on this route of travel, terrain-restricted points are selected for interdiction. In most cases, a node is a terrain restricted point.

The convoys are modeled as having a head and a tail entity. The vehicles in between represent the time it takes for a convoy with all its elements to pass from one point to another point. This is referred to as passage time. Since the length of the convoy is stochastic, the vehicles' distance in between the head and tail of the convoy varies by a triangular distribution. The head of the lead unit in each convoy starts at "time now" (TNOW), which represents zero time. The tail of the convoy is computed to start behind the head of the convoy at the time TNOW plus the unit length divided by the rate. Dividing the unit length by the rate, also drawn from a triangular distribution, converts the distance to time so TNOW can be added to it. All times are in hours. Since the interval between convoys is also stochastic, a sample taken from a triangular distribution divided by the rate of unit one determines how far back the second unit head is located. Adding this time (interval between units divided by rate) to the time for the tail element of the first convoy gives the starting time for the head of the second convoy. As with convoy one, the location of the tail element for convoy two is computed after sampling from a triangular distribution with parameters for unit two's lengths. This procedure continues until all convoys are on the road with a head and tail entity. The march rates for all convoys behind the first unit on each route are adjusted to insure that the units finish in the same order in which they start. Rates are adjusted by decreasing or increasing the rate, depending on whether it is greater or less than the lead rate. In actuality, the rate of the lead unit determines the march rate for units following it because failure to maintain a rate less than or equal to the lead rate would create congestion or an accordion effect on the vehicles.

Sortie Attack

The movement of the convoys in the preceding section represents the steady state condition of the system under study. The time to travel the portion of the network being examined represents the time that the MRD would take without any impediments such as interdiction. This section will outline how air interdiction might affect the steady state time. Examining the system with interdiction will give insights into how additional time delays will affect arrival times of convoys at the battle area. The difference between the steady state time and the time with interdiction will represent the delay time. Also, the destruction of vehicles computed as a result of interdiction represents the decrease in combat power of the MRD.

A flight of two aircraft, each loaded with 12 500-pound MK-82 general purpose bombs, represents the strike mission. The assumption is made that the aircraft are F4D/E, with a 6000-foot slant range, in poor combat conditions, using a dive toss bombi g run. Each aircraft is also assumed to make one pass and drop all its bombs in pairs. Figure 2.3 depicts the assumed pattern of impact. Consulting JEMM, Weapons Characteristics (Ref 39:1-184G), an unclassified estimate was obtained on crater diameter for a MK-82 dropped on 12 inches of concrete with medium soil underlayer. JEMM says to treat roads as runways. The crater estimate for this 12 inches of concrete was about 35 feet. Even though the road being modeled is not 12 inches of concrete, the crater diameter of the bomb is assumed to be 30 feet. In reality, the crater diameters would probably be greater due to the road material not being 12 inches of concrete. The intravolometer setting is assumed to be set so that the

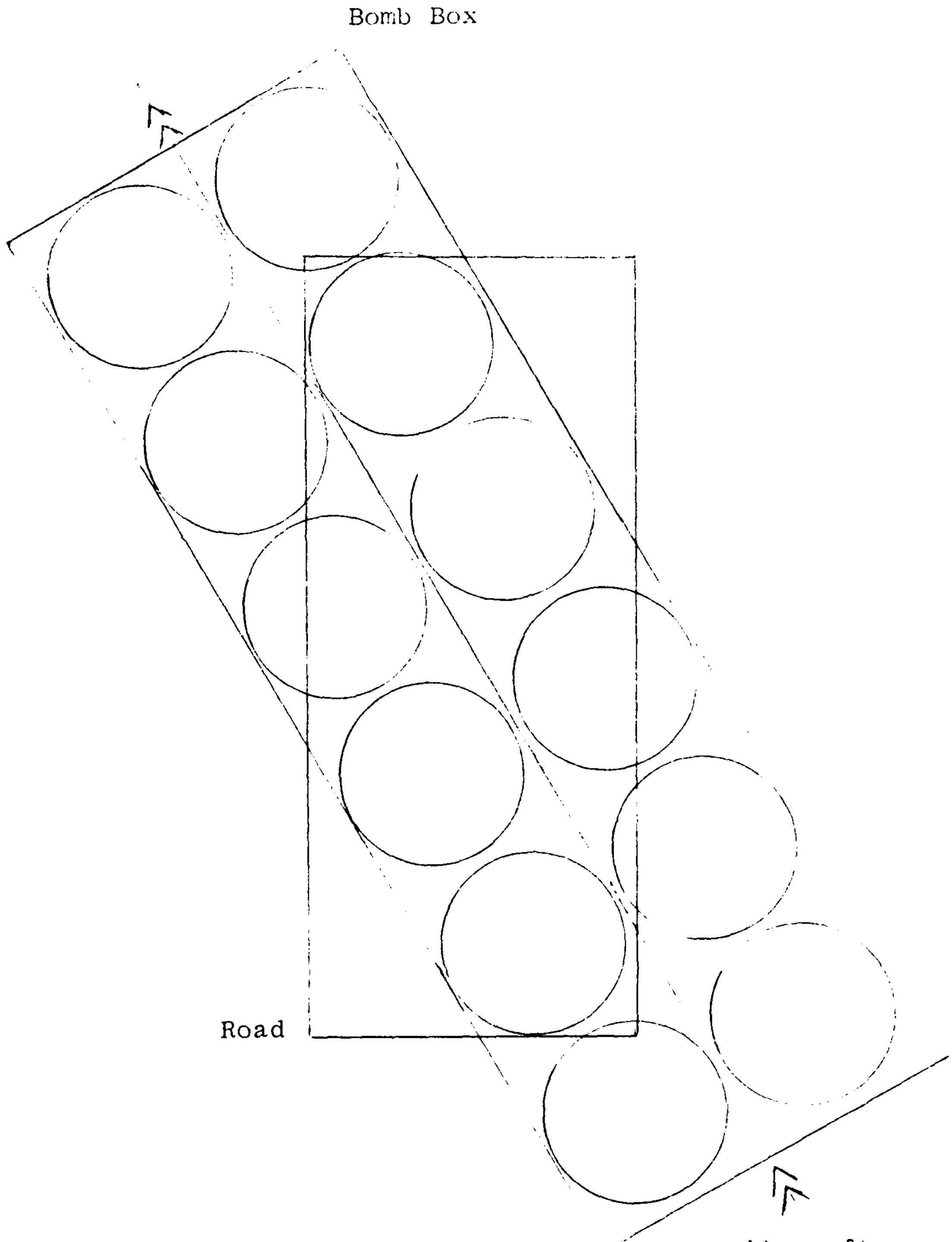


Fig 2.3. Assumed Bomb Pattern

timing of release between bombs would give the pattern in Figure 2.3. A 25-mil circular error probable (CEP) is also assumed to arrive at a 150-foot CEP in the ground plane. The 150-foot CEP was computed by using the relationship that 1 mil at 1000 feet equals 1 foot. So, multiplying the slant range by the 25-mil CEP gives 150 feet.

Since the intention of this model is to capture interdiction effects, and not aircraft interdiction, the interdiction of the roads is modeled by determining the probability of cutting an assumed 50-foot road width. To gain an understanding of the geometry involved, a model was built to examine the problem. This appears in Appendix B. By varying different parameters, such as CEP, range error probable (REP), deflection error probable (DEP), attack angle, target width, and target length, an estimate was obtained of the probability of cutting the assumed road for 1000 bomb drops. Next, a group of fighter pilots was consulted about the reasonableness of the estimate obtained. Conditions as outlined above were also presented to them. Based on the geometry model parametric studies and these conversations, the probability arrived at was 0.35. Thus, based on the given conditions, roads are assumed to be cut 35 percent of the time by a two-aircraft sortie.

Another assumption made was that aircraft penetrate the FEBA without loss. Also, enemy engagement of the attacking aircraft is ignored, but partially considered in the CEP calculation by assuming poor combat conditions. A higher CEP allows for target area unfamiliarity and the threat environment.

While a specific scenario is fixed for this study, in reality the aircraft interdiction process is a complex one that is full of variability and uncertainty. For instance, each aircraft has its own system weaknesses and strengths, pilots have different levels of proficiency, delivery conditions are dependent on such factors as air speed, delivery angle and target type, and the threat environment is such that the probability of success of aircraft penetration, target attack, and egress is decreased.

The total number of daily sorties available for the corps sector is assumed to be 30. Considered was that a percentage of aircraft would be nonoperational and that about 10 percent of the total aircraft available would be committed to other special missions. From the remaining number of aircraft, an allocation has to be made of aircraft to interdict this three-route move of the MRD. A further complication involves knowing that the MRD under study is probably one of several forces in the corps sector that require interdiction such as Figure 1.2 depicts. Thus, the allocation of sortie resources within the corps sector is among competing activities. The actual basis for allocation will involve the design of the experiment, to be discussed in Chapter IV.

Damage Due to Sortie Attack

The convoys are assumed to be targeted at the head element. To simplify calculations of vehicles damaged due to the air strike, any vehicles within the radius of the bomb impacts are considered destroyed. Because the majority of targets bombed are hard targets (tanks), the assumption made is that bombing would kill at most one vehicle per pass. So, a total of two vehicles are assumed killed. Once the destroyed vehicles are subtracted, the convoy length is adjusted to reflect the loss in vehicles.

Delay Due to Sortie Attack

An Algorithm for Determining Delays Imposed on Ground Forces Due To Interdiction Air Strikes Revisited, Technical Paper 5-79 (Ref 3), was consulted to understand more about air interdictions and the effects on ground forces. Other papers examined include Minutes of an Exploratory Meeting on Interdiction Study, AC 243, NATO Panel VII (Ref 46, NATO RESTRICTED) and An Algorithm for Determining Delays Imposed on Ground Forces Due to Interdiction Air Strikes, Technical Paper 3-79 (Ref 25, NATO RESTRICTED). These two references were used for background information.

TP 5-79 explains the "four mutually exclusive, exhaustive delay events, with associated delay times defined as follows:"

> Heads Down Time (HD)--the initial reaction of the Red Force to Blue air attack.

Damage Assessment Time (DA)--the time required for a commander to receive reports from his subordinates, assess the situation, and then report to his higher headquarters.

Damage Control Time (DC)--the time required to treat personnel casualties (first aid) and recover damaged and/or slightly damaged vehicles.

Impaired Movement Time (IM)--the time required to bypass craters and remove burning vehicles and other obstacles from the road (Ref 3:1).

This study does not calculate the individual times for the above four events. Instead, based on ideas obtained from the NATO Panel study, an assumed distribution for delay time is used. If the convoy route is cut and block, sampling is made from a triangular delay distribution with minimum, mode, and maximum values of 30, 34, and 38, respectively. This time is in minutes. If the road is not cut, then a delay time is still imposed to capture the time associated with getting the convoy reoriented, reporting to higher headquarters, and negotiating the road damaged by the strike. Sampling is made from another triangular distribution containing parameters for minimum, mode and maximum values of 10, 12.5, and 15, respectively. Triangular distributions are selected for the same reason given in development of convoy movement parameters.

Since the lead element of each convoy is a reconnaissance element operating in front of the convoy at greater distance than the interval between the other units, interdiction of this lead element allows it to radio back the resulting attack, whether successful or unsuccessful. The rest of the convoy is then assumed to take an alternate route to bypass the obstacle or damaged road on the original route. The lead element is assumed to be delayed by the amount required to repair and negotiate the obstacle and continue on the original route. The idea is to continue moving the rest of the force and minimize delay or bunching of vehicles as an obstacle is approached and negotiated. The lead element is not allowed to turn around and attempt to resume its lead place in the pack. Convoys continue in the route specified without attempts to remerge them because to merge remnants with the original convoy requires waiting time for some part of the convoy. This is considered unrealistic given that Warsaw Pact doctrine requires constant movement forward.

If the lead element is not interdicted, but allowed to pass on, then the next element of the convoy will be bombed. By allowing the reconnaissance element to go on uninterdicted, the main column presents a bigger target of opportunity due to shorter intervals between units. The reaction time to radio back the bombing and the issuance of orders to change routes would cause the following units to quickly close the interval. Assuming, an average interval of 4 kilometers and an average rate of 25 kilometers per hour, a unit following the interdicted one would close the distance between them in about 10 minutes. Unless immediate action is taken, units begin to pile up. This model assumes that the second unit will not be able to find a bypass and waits behind the lead unit until the obstacle is repaired. The third unit and others behind it are assumed to have received the order to take an alternate bypass. As before, the blocked units, once the obstacle is negotiated, do not rejoin the rest of the convoy at a point down the original route.

A few observations are in order to discuss the implications of the above convoy actions. The unit's electronic signature surfaces when communication silence is broken to report the attack to higher headquarters. This action may facilitate target acquisition or detection. Also, interdicting the reconnaissance element in the column and successfully cutting the road will leave the rest of the convoy without a quick obstacle repair capability to its front because the lead element will have to fix or negotiate the obstacle. Taking away this capability by delaying and separating it from the main column reduces quick obstacle re air. It also reduces MRD advance warning time about future activities. At any future obstacles, the convoy will have to depend on what is at hand to repair, that is, manpower, or wait for some type of engineer equipment to make its way up to affect repair. On the other hand, interdicting this element will give the main body of the convoy more time to react and select another route. This would allow the main body to move on without slowing it down.

Interdicting he lead element of the main body appears to offer more in the way of destruction and disruption. Not only is there less reaction time available to following units to make a quick route change, but there is more bunching of units. A more dense and lucrative target is created for wide-area anti-armor munitions (WAAM). The possibility then exists for greater disruption and destruction. By modeling the process of moving separated units into different routes, congestion at some future point is eliminated. Otherwise, units will be stopped while waiting for another unit to be inserted. Vulnerability is decreased, but disruption is increased.

All the above assume perfect intelligence and good weather.

Missile Attack

Once the road is interdicted, a determination needs to be made about retargeting the same area with a ground launched Army missile loaded with wide-area anti-armor munitions (WAAM). As mentioned previously, knowing that there is a stationary target located behind a road blockage removes the uncertainty of target location. Cratering or damaging the road with air interdiction should create a target suitable for WAAM engagement. A generic missile capable of carrying WAAM is assumed to have an approximate CEP of 110 feet. This CEP is obtained by using unclassified Eq (1) taken from a letter requesting data from the Corps

Support Weapon System (CSWS) office, Fort Sill, Oklahoma (Ref 15:3) (CONFIDENTIAL). The system CEP is assumed to have a circular normal distribution.

$$\text{CEP System} = \sqrt{\text{CEPMPI}^2 + \text{CEPP}^2}$$

where

$$\text{CEPMPI} = 0.5877(\text{RSIGMPI} + \text{DSIGMPI})$$

$$\text{CEPP} = 0.5887(\text{RSIGP} + \text{DSIGP}) \qquad (1)$$

Values assumed for computing system CEP follow:

Range: 100 KM

RSIGMPI: 20 M (65 feet)
(Range deviation, mean point of impact)

DSIGMPI: 20 M (65 feet)
(Deflection deviation, mean point of impact)

RSIGP: 20 M (65 feet)
(Range deviation, precision)

DSIGP: 20 M (65 feet)
(Reflection deviation, precision)

The shape of the dispersal pattern for the WAAM is assumed to be elliptical with a minor axis value of 46 meters (approximately 150 feet) and major axis value of 240 meters (approximately 800 feet). All vehicles within this pattern are assumed killed. Assumptions made for the missile include reliability of one (for pre-launch and in-flight) and perfect communication and intelligence to allow for notification of air interdiction mission. Also, another assumption made is that the WAAM always impacts with the major axis of damage parallel to the road. As with the air sortie interdiction, the missile attack is not modeled explicitly. How it is done follows in the next section.

Damage Due to Missile Attack

A probability density function is computed to determine damage due to WAAM attack. Knowing that the minimum spacing and maximum spacing between vehicles are 25 and 50 meters (approximately 80 and 160 feet), respectively, a methodology is needed to determine the probability of killing vehicles based as a function of vehicle spacing and munition impact. Vehicles are assumed to be on the roadway center line. An average of both extremes of spacing is determined to be 120 feet [(80 + 160) ÷ 2]. Vehicle spacing is determined by dividing the unit length by the number of vehicles. This number is then converted to feet. Once spacing between vehicles is determined, the value obtained is compared against this average. If the value obtained is less than the average, then the assumed interval between vehicles is 80 feet, and 160 feet otherwise.

Using the minimum interval of 80 feet and an assumed vehicle length of 20 feet, an average of 8 targets are hypothesized as being within a road cut made by the ellipse of between 750 and 800 feet. Figure 2.4 depicts the elliptical pattern given that the roadway cut is ±400 feet from center of missile impact, or 800 feet for the total length. This represents the maximum cut possible since the major axis is 800 feet long and 8 vehicles is the maximum

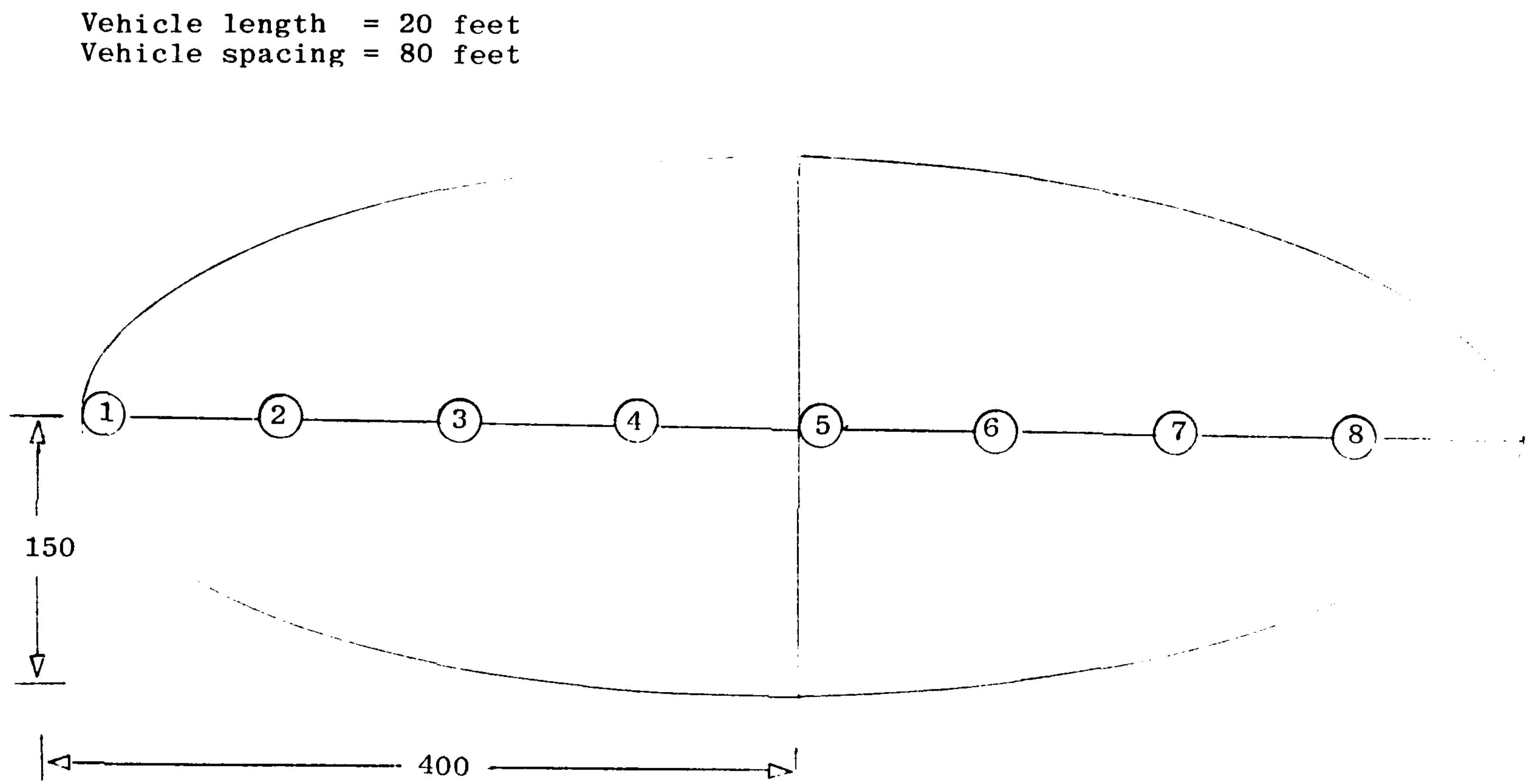


Fig 2.4. WAAM Coverage For Minimum Vehicle Interval

number that could fit into this interval given their length and interval. Using an interval of 100 feet (20 + 80 = 100), subsequent calculations are made to determine the average number of vehicles within that interval. Another assumption made is that a half or greater portion of a vehicle within this area cut is also considered destroyed. Table 2.2 represents the interval road cuts and the number of vehicles killed within that distance.

TABLE 2.2

Road Distance Cut and Number of Kills--
Minimum Interval

Distance (feet)	Kills	Probability
cut < 50	0	0.1074
50 < cut < 150	1	0.0068
150 < cut < 250	2	0.0118
250 < cut < 350	3	0.0238
350 < cut < 450	4	0.0338
450 < cut < 550	5	0.0584
550 < cut < 650	6	0.1052
650 < cut < 750	7	0.2282
750 < cut < 800	8	0.4246

An equation for an ellipse is used to determine the distance of the y cut knowing the x distance cut.

Equation: $$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \qquad (2)$$

where x = value of cut in the x direction
a = the value of the major axis
y = value of cut in y direction
b = the value of the minor axis

This equation is solved for y by taking one half the maximum x value in each interval. This y value is then normalized by dividing it by the system standard deviation of 93.43 feet. A normal distribution table is then used to integrate from zero to this normalized value. Doubling this value and subtracting it from the value obtained for the previous y cut (explained below), gives the probability of killing that many vehicles.

Two exceptions to this method are determining the probability of zero and eight kills. Any y value greater than the minor axis value is outside effective radius of kill. Dividing the minor axis by the standard deviation gave a normalized value. Finding the probability for this value in the normal tables and doubling it, then taking its complement gave the probability of zero kills. Once the probability of zero kills was known, 0.1074, the remaining probability mass, 0.8926, was used in calculating the other probabilities. For example, using the doubled table values of one kill, 0.8858, and subtracting it from 0.8926, gave the probability of killing exactly one vehicle, 0.0068. Using the doubled table value for two kills, 0.8740, and subtracting it from the doubled table value for one, 0.8858, gives a probability of 0.0118 for killing exactly two vehicles. This process is continued to determine Table 2.2. The complement of the sum of the number of zero to seven kills then gives the probability of eight kills.

The same process is used in arriving at the values in the bottom half of Table 2.3, the case for the maximum interval. Instead of 80 feet between vehicles, a 160 feet interval is used. A random number drawn from a uniform (0,1) distribution will then be used to determine destruction by WAAM. Vehicles destroyed are then subtracted out of the rest of the convoy. A new convoy length is then computed and the delay time associated with this attack is determined.

TABLE 2.3

Road Distance Cut and Number of Kills--
Maximum Interval

Distance (feet)	Kills	Probability
cut < 170	0	0.1074
170 < cut < 350	1	0.0424
350 < cut < 530	2	0.0804
530 < cut < 710	3	0.2290
710 < cut < 800	4	0.5408

Multiple missile attacks are treated as independent events by assuming targeting points on the same convoy being at least four standard deviations apart. Treating multiple missile shots this way maximizes coverage of a linear target like a convoy.

The delay time associated with this attack is discussed next.

Delay Due to Missile Attack

The same four mutually exclusive delay events associated with air interdiction also apply here. Although the road is not cut as was done with the aircraft interdiction, damage due to missiles imposes delay due to more likely destruction of vehicles and disruption over a wider area due to the wide area coverage of the WAAM.

Delay time imposed varies as a function of number of vehicles killed and the completed actions necessary prior to commencing the march. This model assumes that the missile attack comes at the end of the impaired movement (IM) time due to air attack. The delay associated with the missile attack is added to the old delay time.

Imposed delay time varies as a function of number of vehicle kills. If five or less vehicles are killed, then delay time is obtained by sampling from a triangular distribution with parameters 15, 18.5, and 25. For kills less than or equal to 10 vehicles, the triangular distribution parameters are 22.5, 30.0, and 37.5. Finally, if the number of kills is greater than 10, the distribution parameters are 30, 41.5, and 50. These parameters were obtained by comparing against the parameters for the air sortie case. While no actual distribution exists for interdiction with WAAM, the distributions hypothesized above represent the idea that as more targets are destroyed, more delay time is imposed because more time is needed for clearing roadways of destroyed vehicles, administering first aid, and restoring order to continue the march. Once the unit accomplishes the required actions, it is ready to continue movement.

Summary

Chapter II has described how the problem was conceptualized so that computerization can begin. An MRD was described as broken down into 44 units. The 44 units traveling on the hypothesized three-route network represent the steady state condition of the system. Route interdiction consisted of bombing the road at preselected points so that the convoys are blocked. The assumption was that the aircraft and convoy to be interdicted arrived simultaneously at the point of interdiction. The strike mission consisted of a flight of two aircraft each making one pass and dropping all 12 500-pound bombs in one pass. The resulting stationary convoys would then increase the probability of striking the convoy with one or more missiles loaded with wide-area anti-armor munitions (WAAM).

Chapter III follows with the computerization of the system described.

III Simulation Model

This chapter describes how the system structure in Chapter II was computerized. The description includes the convoy movement of the 44 units through the road network, the effects of interdiction on the reconnaissance element on each route, and the subsequent effects on the arrival time for the MRD. The model structure is network based and it incorporates the use of nodes to model specific geographic features. The time to travel between nodes represents the convoy travel time for the distances represented between nodes.

The network structure of STOPEM and its interdiction process were both modeled using Simulation Language for Alternative Modeling (SLAM). SLAM is a powerful simulation language that provides the user multiple capabilities to model networks, discrete events, and continuous events or any combination of these three processes. Since the system structure has a network base and interdiction processes, SLAM's power and flexibility provided the capability to model the network with event nodes. The interdiction processes, representing changes of state within the system, were modeled within the event nodes utilizing user-written subroutines. Another feature of SLAM allows the modeler to assign up to 100 attributes per entity. However, STOPEM only uses 16 attributes per entity SLAM's global variables, XX(·) with their values known to all subroutines within the program, provided the capability to denote such events as interdiction and to act as indicator variables. One capability not exercised, but available to global variables is SLAM's capability to provide time statistics on global variables specified by the user. This capability is above what would normally be associated with global variables being passed within user-written subroutines. Finally, the waiting time for interdicted convoys was modeled using AWAIT nodes, a form of QUEUE node. The few SLAM capabilities exercised in this model represent but a small portion of SLAM's overall power. The reader is referred to Introduction to Simulation and SLAM (Ref 49) for a more complete description of the language and SLAM's capabilities.

Network

A total of 44 MRD units are entered into the road network represented by the Figures 3.1, 3.2, and 3.3, corresponding to Routes BLUE, GREEN, and RED, respectively. This represents the MRD movement on the hypothesized three-route march through the portion of the corps sector being examined. Route BLUE, Figure 3.1, will be used to explain the computerization. References to EVENT and ENTER nodes, and other SLAM structures will be made using node labels associated with each structure. This label is located immediately below the structure in the referenced figures. Similar logic was used on Routes GREEN and RED.

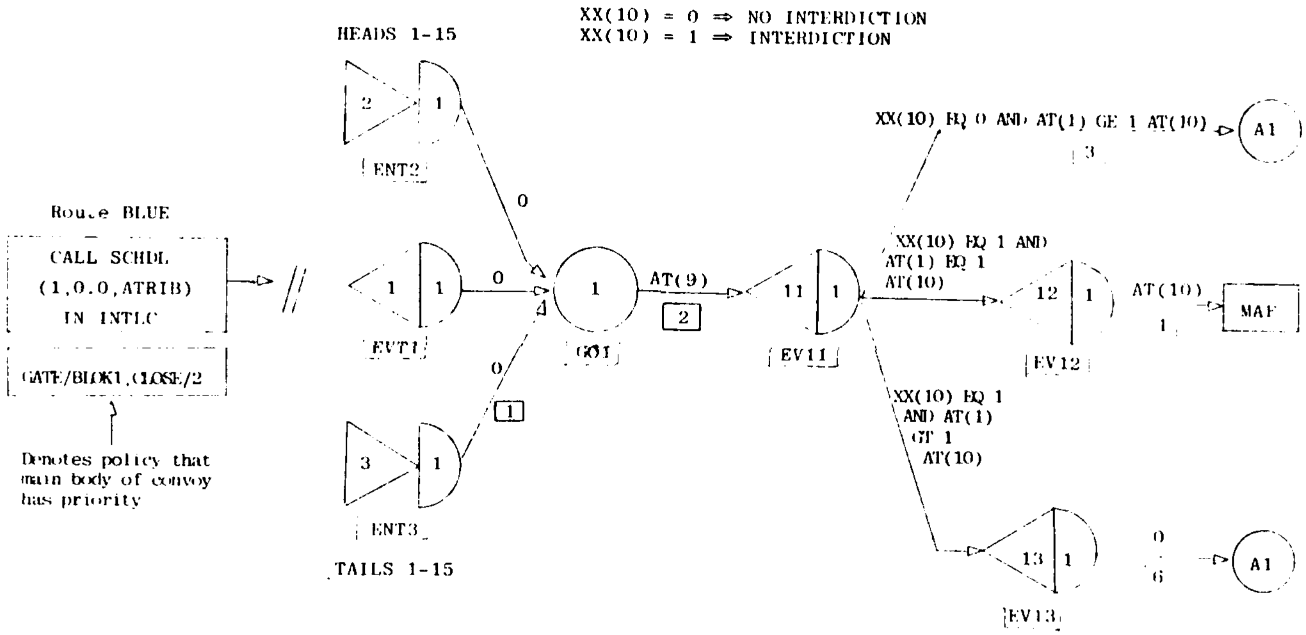


Fig 3.1. Route BLUE

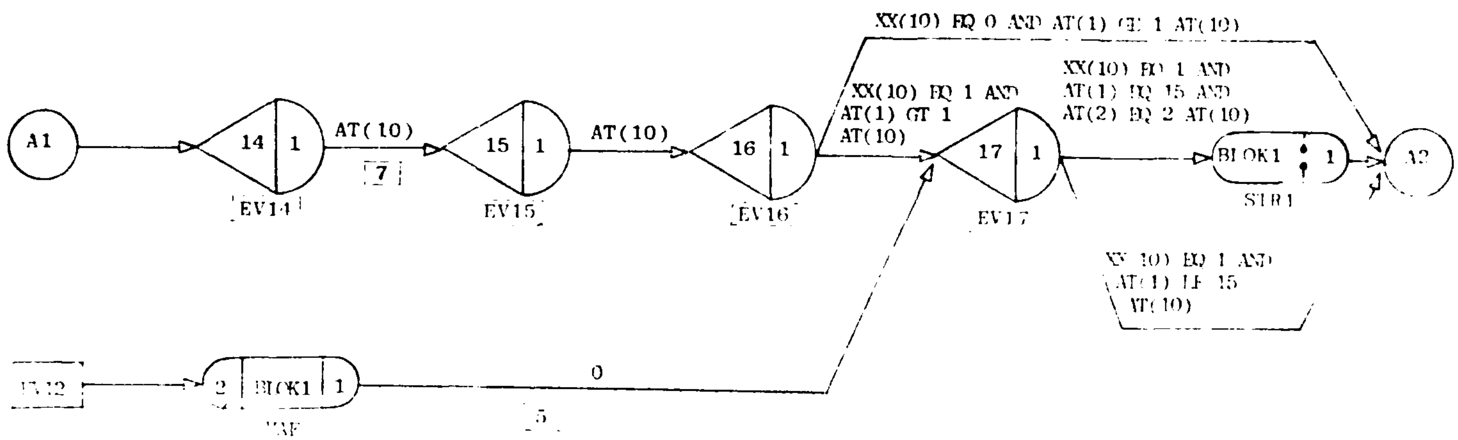


Fig 3.1. Route BLUE (Continued)

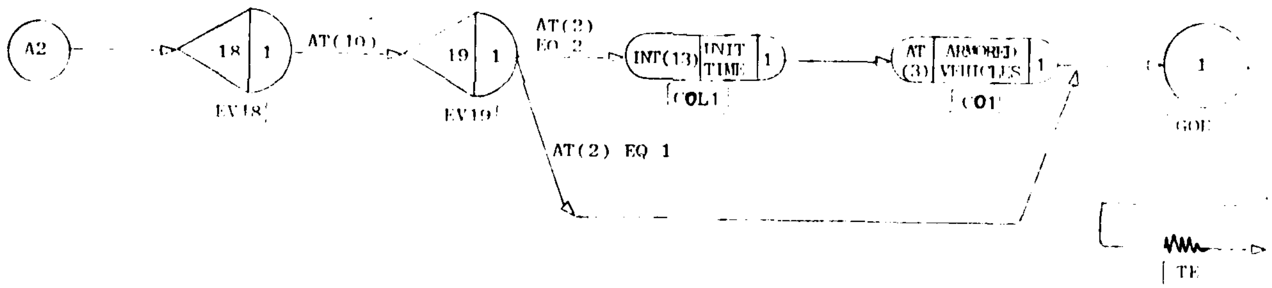


Fig 3.1. Route BLUE (Continued)

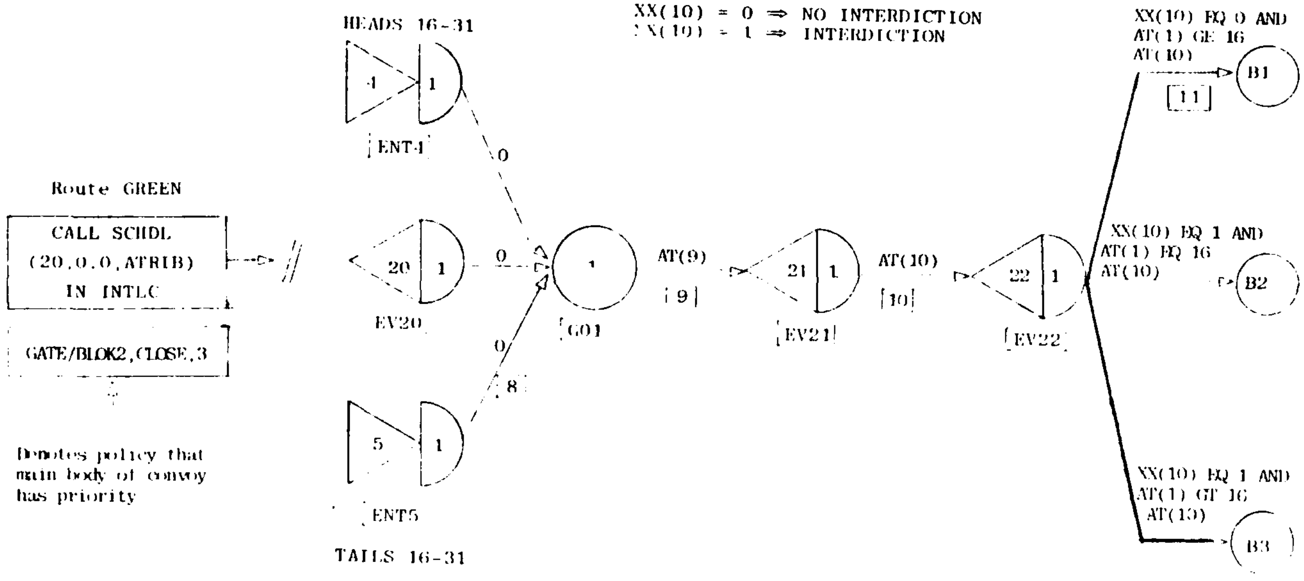


Fig 3.2. Route GREEN

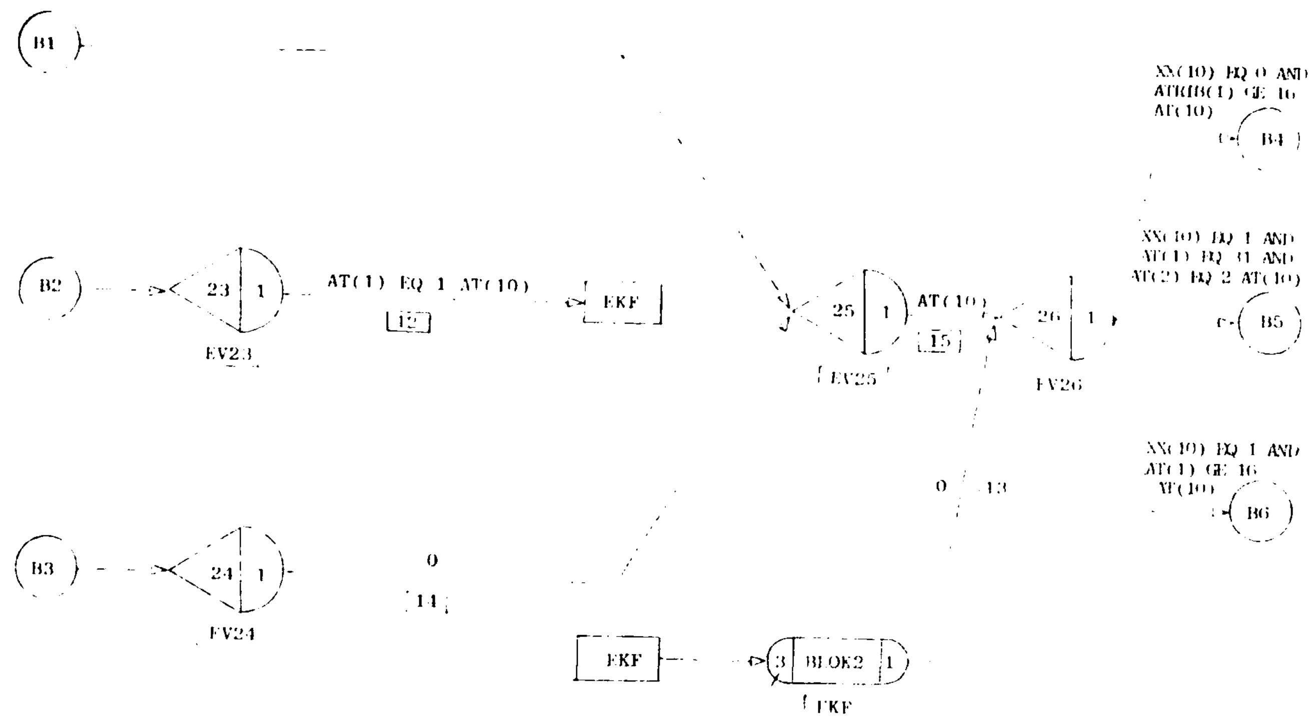


Fig 3.2. Route GREEN (Continued)

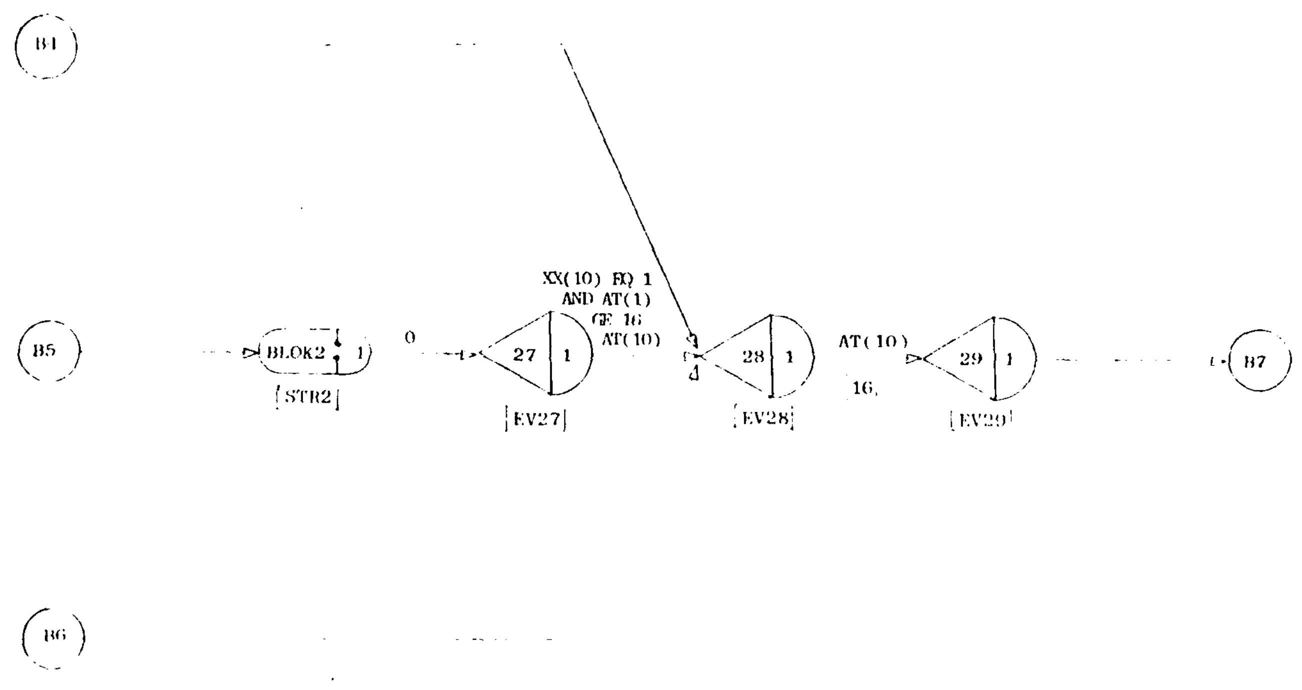


Fig 3.2. Route GREEN (Continued)

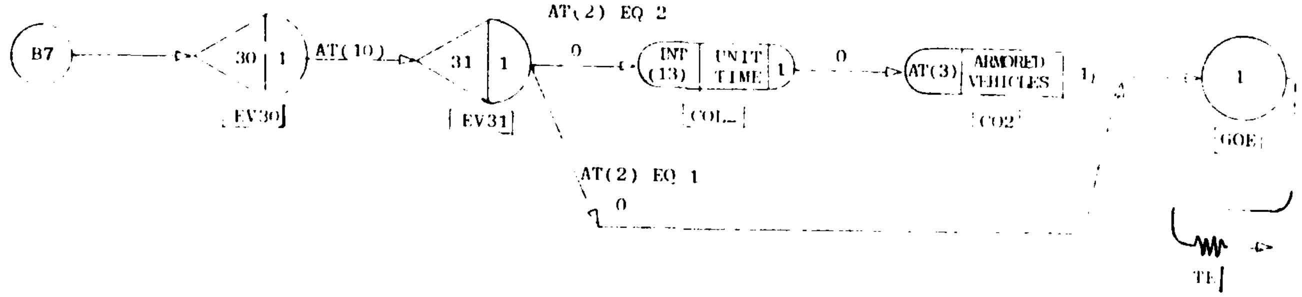


Fig 3.2. Route GREEN (Continued)

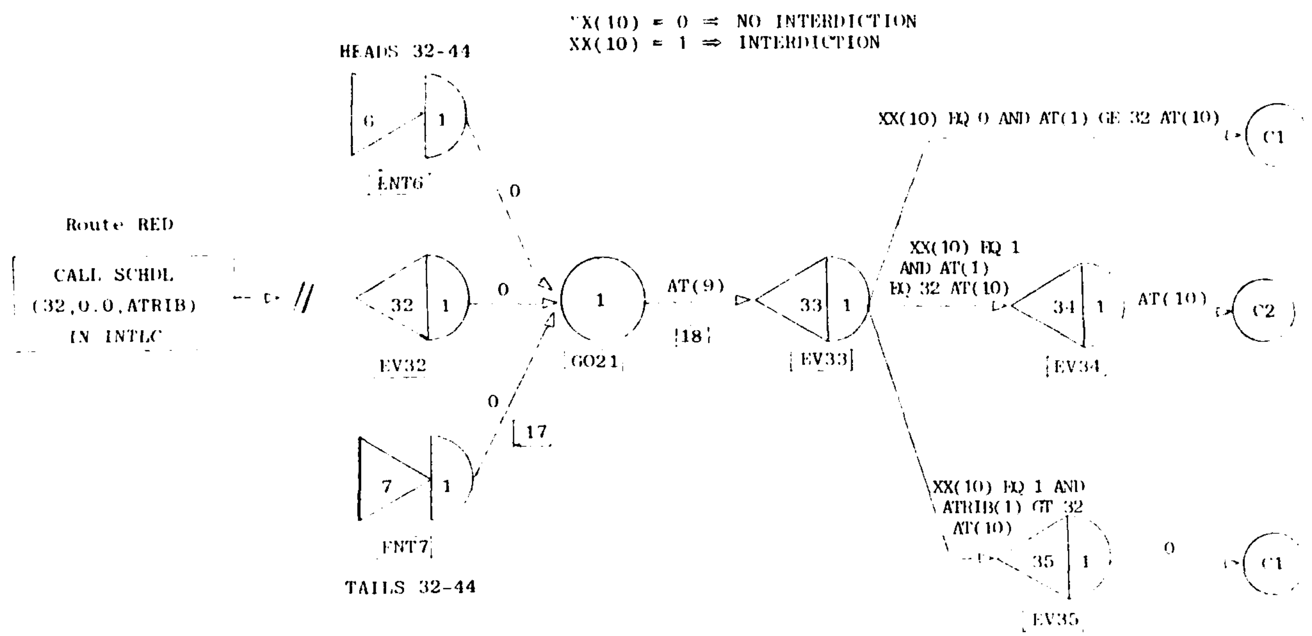


Fig 3.3. Route RED

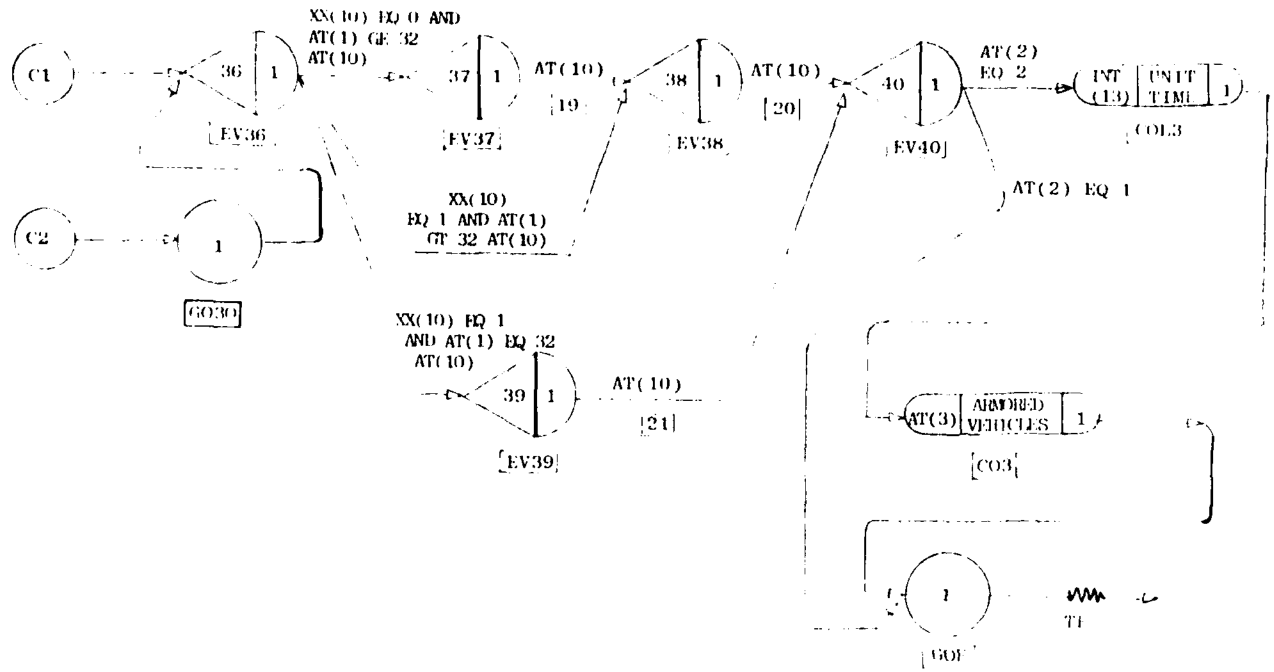


Fig 3.3. Route RED (Continued)

An initialization subroutine, INTLC, is used to establish the units for the model. The reader is referred to Appendix A, the SLAM computer code, for further details. Each of the 44 units has 16 unique attributes. Attribute one, the unit number (same number that appears in Table 2.1), is used to rank the units within the model structure. SLAM uses a system of files to maintain order as specified by the user. This order is specified as a ranking within the file. The entity file ranking specified for file one was low value first of attribute one, the unit number. This means that unit one with all its associated attributes is first, unit two is second, and so on within the file. This ranking scheme allowed for ease of accessing the units out of the file and scheduling them for movement as will be explained shortly. Table 3.1 contains a description of the other 15 attributes. Other attributes within this table will be explained as they are introduced.

The start of convoy movement on the road network is initiated in the model by the last three statements in INTLC. CALL SCHDL (1, 0.0, ATRIB) for Route BLUE is a SLAM statement that schedules event one to occur at time of 0.0 or at the start of the simulation. The last argument, ATRIB, is a vector array of an entity's attributes being called within that event. SLAM dimensions ATRIB to a vector (1, 100), but the model only has a (1, 16) array since each entity has 16 attributes. All 40 events used in STOPEM are found within

TABLE 3.1

Entity Attribute Description

Attribute Numbers	Description
1	Unit designator
2	Head/Tail designation (1 = Head, 2 = Tail)
3	Number of track vehicles
4	Number of wheeled vehicles
5	Minimum unit length (km)
6	Maximum unit length (km)
7	Average unit length (km)
8	Unit length (km)
9	Travel time for first node (hrs)
10	Travel time for subsequent nodes (hrs)
11	Day travel rate, mixed convoy (km/hr)
12	Interval between convoys (km)
13	Convoy start time (hrs)
14	Convoy finish time (hrs)
15	Event code (Assigned by SLAM)
16	Event time (Assigned by SLAM)

subroutine EVENT. The schedule statements for the three routes (1, 20, and 32) represent the event number that initiates convoy movement for that route. Within each event, the first unit and its associated attributes are referenced by a CALL COPY (entity, file number, atrib) statement that copies the referenced entity with associated attributes from the appropriate file. For Route BLUE, since unit one is the advanced guard for that regiment, it is called first from file one. Since the time keeping mechanism of SLAM is stopped while within an EVENT node, all operations within the EVENT node are of zero time duration. It is within the EVENT nodes that attributes can be changed to model system structure changes.

Event one, EVT1, schedules the entry into the network for the head and tail entities for convoy one and the head entity for convoy two. This is accomplished by the use of the SCHDL subroutine. A counter variable, I1, is used within event one to keep track of which unit out of file one is being addressed. Its initial value is assigned by the global variable XX(1), initialized to one and incremented by one before the event termination. Thus, I1 is initially set equal to one. Within GREEN and RED, the counters are initialized to 16 and 32, respectively, corresponding to the lead units on each route. To regulate convoy rates, Subroutine RESHUF1 is called. A global variable XX(4) is assigned the rate value for unit one. XX(4) is then used in subsequent calls to RESHUF1 to compare against other unit rates. Based on whether the following units have rates that are less than or equal to or greater than this global variable, unit rates are adjusted up or down to match the lead unit rate. RESHUF2 and RESHUF3 perform the same function on Routes GREEN and RED. This assumes that all units within that convoy maintain the rate set by the lead element. The head of the lead unit starts the convoy movement at "time now" (TNOW) of zero. Its entry time into the network is placed in attribute (13). ENTER node ENT2 inserts the head entity into the network. As its name implies, the ENTER nodes functions to place entities into the network at the appointed time. The tail entity for the first convoy is scheduled to enter the network at enter node ENT3 at the time equal to the passage of vehicles between the head and tail. The length of the convoy, attribute (8), is divided by the rate, attribute (11), to obtain the travel or passage time. Attribute (8) was sampled from a triangular distribution composed of parameters of attributes five, six, and seven. This calculated time is added to the time of entry for the head entity, which is zero for the first unit, and used to schedule entry time for the tail. To distinguish the tail from the head, the value of attribute (2) is changed to two. The time it enters the network is then stored in attribute (13). I1 is incremented by one and the attributes of unit two are copied into the array ATRIB. The head entity of the unit two is scheduled to arrive at the time that the tail of one entered plus the time between the tail and itself. The value of attribute (12) for the first unit, the interval between the two units, is assigned to the variable CINT1 (CINT2 and CINT3 on GREEN and RED, respectively). This distance is converted to time by dividing CINT1 by the adjusted rate of attribute (11) for unit two. RESHUF1 is called again before this operation to insure the rate is adjusted to match the lead rate. The time is then added to the entry time for the tail of unit one to obtain the entry time for head two. This calculation reflects when the head of unit two enters the road network. As with the other two entities, its entry time is recorded in attribute (13). To continue this process, the scheduled time of convoy two triggers event one again. The last operation before exiting the event is to increment XX(1) by one so that the next time event one occurs, the counter I1 will be set to two to schedule the tail of convoy two and the head of convoy three. This cyclic process continues until all convoys are moving on the road network.

At the conclusion of each event, the SLAM event calendar, which keeps record of when to schedule entities, is updated with the unit and its associated attributes. When TNOW equals the value of that entity on the event calendar, it is processed at the next SLAM structure if the duration activity between the two structures is zero. The activities between SLAM structures represent the branches where explicit time delays are modeled. Otherwise, if the duration activity is greater than zero between the structures, the entity takes that long to get to the next structure. This represents the convoy movement between nodes.

The duration between structures mentioned above represents the time in the model associated with the network travel. This aspect is modeled by dividing the distance to travel between event nodes by the rate. For the first node, this value was assigned to attribute (9). For subsequent travel distances, the travel time is assigned to attribute (10). Both values for these attributes are initialized in INTLC, but recomputed within EVENTS 1, 20, and 32 because convoy march rates were adjusted in these events.

Other attribute values that characterize each unit are read in by INTLC for appropriate attribute array for all units. These values include designation for the head, and the number of wheeled and track vehicles.

Discrete Events

As was mentioned previously, SLAM provides the capability of modeling the system changes of state within each event node. For example, within selected event nodes user-written Fortran subroutines are used to model system changes such as interdiction due to aircraft and missiles. Before interdiction is described, a network description is given of the system's steady state. The next section then discusses how the interdiction processes are modeled.

Steady State. Figure 3.1 is the description of the system steady state. An indicator variable, XX(10), is used to denote when there is interdiction. A value of zero denotes steady state, while a value of one denotes interdiction. As shown on Figure 3.1, entities leaving the two enter nodes encounter a GOON node GO1. This GOON node functions as a continuation node between EVT1 and EV11. The branch or activity time from the enter nodes to GO1 is zero because there is zero travel time involved between the structures. The activity time between GO1 and EV11 represents the travel time for convoys. The number two in the box beneath the branch between the structures is the activity number that uniquely identifies that branch. Once at EV11, representing event eleven, a conditional statement is used within the event node to recompute attribute (10) since it changed from the value computed in INTLC. An exiting entity EV11 encounters conditional branching. The value of one in each EVENT, ENTER and GOON nodes denotes that only one branch can be taken on the exiting end of the structure. This logic models the convoys taking only one route. Since the system is at steady state, that is XX(10) equals zero, and all units on Route BLUE are to go on this branch, that is attribute (1) is greater or equal to one, only one branch can be taken and that is the top branch. The value for attribute (10) computed in EV11 is used for the duration from EV11 to EV14. This time reflects the passage time for the head and tail entities for each convoy. The same process continues through the remainder of the network. Values for the convoy passage for the next branch are computed in the preceding event node. The conditional statement at EV16 routes the entities to EV18 since it meets the top condition first and only one branch can be taken. EV19 is the last event for Route BLUE. A conditional statement within EV19 permits only the tail entity of each convoy to enter the enclosed subroutines. The subroutine calculates total time in the system for each entity by subtracting from TNOW the value of attribute (13), when the entity entered the road network, and assigning the value to attribute (14). Selected values are sent to a tape, which was used in model verification, discussed in Chapter IV. A sample of these tapes 14 and 17 appear in Appendix E. Also, event 19 maintains a count of armored vehicles by incrementing XX(23) every time an entity enters EV19. When the last unit finishes (its tail entity), its finish time is assigned to XX(19). This represents the total travel time for all units on BLUE. Subroutine GAFMGF is then called to increment XX(22) by XX(19) so that XX(22) represents the total time for all three routes when the other two route finish times are added to it also. For the other two routes, this occurs at EV31 and EV40. XX(28) is incremented by one within EV19 and used as a test within GAFMGF to determine when the last unit of the MRD has finished. Once the very last unit has finished, an average finish time for the MRD is obtained and divided into the total number of armored vehicles to arrive at the measure of effectiveness, number of armored vehicles per unit time. This value and other values (discussed in Chapter IV) are sent to an output tape. A sample of this output tape appears in Appendix C.

Upon exiting EV19, conditional branching occurs again. The head entities take the bottom branch and are routed through another GOON node, GOE, to the terminate point where the entity disappears from the network. This action corresponds to the head of the unit arriving at its release point. The tail entity takes the top branch and is routed through two COLLECT nodes. These nodes collect statistics on the entities passing through them. The collection information is a function of the argument in the left portion of the node. For example, COL1 collects interval statistics on the time between arrival of entities based on attribute (13). CO1 collects the value of attribute (3), armored vehicles, and records it. At the end of each simulation run, the statistics collected are printed in table format. The tail entity travels through GOE on its way to the terminate node, where it is deleted from the system. The tail entity arriving at this point represents the completed movement of each convoy.

Interdiction Processes. By changing the value of XX(10) to one, the system structure now has interdiction. Another global variable, XX(11), denotes the number of missiles targeted against convoys. The combination of these variables denote interdiction and the levels of interdiction within the model. Level of interdiction is defined as the combination of one sortie and either one, two, or three missiles. These levels will be discussed further in the design of the experiment.

All processes discussed in the steady state section pertaining to convoy movement and calculation of travel times apply within this section also. The difference now is that the system structure has been subjected to interdiction. System interdiction is modeled only for the reconnaissance element. STOPEM as it is now does not incorporate targeting the main body. The model interdiction occurs at EVENT nodes 12, 23, and 34 for Routes BLUE, GREEN, and RED, respectively. The basic process within each event is similar. One difference in EVT1 of BLUE is that attribute (9) is recomputed when there is interdiction because, when the reconnaissance element is interdicted and the main body bypasses the point of interdiction, the distance used in INTLC has changed from 64.784 kilometers to 50 kilometers. Since convoy one continues on its original route when it is interdicted, EV11 computes the remaining distance time originally computed in INTLC for attribute (9)

(64.784 - 50 = 14.784). This value divided by the rate is then assigned to attribute (10). This attribute (10) is the time duration from EV11 to EV12. EV11 also calculates the new adjusted attribute (10) for the main body. This new time represents the time to bypass the new distance and is the time duration from EV11 to EV13.

Conditional statements within EVENT 11 insure that the appropriate values for attribute (10) are assigned to the correct units. Conditional branching on the exit end of EV11 only allows unit one, both head and tail entity, to be routed to EV12. The main body of the convoy is routed to EV13 using the bottom branch. This structure simulates main body bypass of the interdicted unit at EV12. This process simulates Warsaw Pact doctrine of pressing forward with the movement. The main body continues on through EV14, EV15, EV16, and EV17. This process portrays the main body moving through the road network without interdiction and is similar to the steady state description. The main body will be discussed again at the conclusion of the discussion of interdiction at EV12.

As the middle branch exiting from EV11 shows, only unit one can take this branch when there is interdiction. The activity duration models the time until the head entity is interdicted at EV12. A conditional statement at the beginning of EV12 insures that only the head entity is allowed to enter the interdiction subroutine. Once within

EV12, subroutine SORTIE is called and a two-ship strike mission is simulated against the head of the convoy. In SORTIE, the variables DTIME and DTIMEP represent a sample from a triangular distribution denoting full or partial road blockage, respectively. SORTIE then draws a sample from a uniform (0,1) distribution and assigns this random variate to the variable PASS. If PASS is less than or equal to 0.35, then the road is considered cut. If PASS is greater than 0.35, then partial road blockage is obtained. A counter variable, XX(9), is incremented by one if the road is cut and zero if the road is partially blocked. Another sample is taken from the uniform distribution to denote the second aircraft pass. The same test is performed on PASS to determine if it is less than or equal or greater than 0.35. SORTIE returns a value for XX(9) of zero, denoting partial road blockage, or a value greater than zero denoting that the road was cut. This value of xx(9) is then tested to determine how much delay time was imposed as a result of interdiction. Attribute (3) is decreased by two to denote two armored vehicle kills. The event time is increased by the delay time imposed, which is either DTIME or DTIMEP. The event time represents when the entity will be scheduled on the network again. SLAM places the entity event time in the attribute that is two greater than the maximum number of attributes for the model. Since the maximum number of attributes is 14, the event time is stored in attribute 16.

Since entity one has suffered damage and delay, the number of armored vehicles is adjusted and its event time is increased by an appropriate amount as sampled from SORTIE.

Since the assumption made was that the delay time due to missile attack would be added to the delay time due to missile attack would be added to the delay due to SORTIE, subroutine MISSILE is called next. A delay time corresponding to the number of kills is sampled from a triangular distribution and assigned to the variables DTMIS1, DTMIS2, and DTMIS3, where the order of variables indicate an increasing time delay. The number of missiles shot is assigned to MSHOT by XX(11). Either one, two, or three missile salvos can be fired at the target. The number of missiles fired will be a function of interdiction policy, resource constraints, and target priority. In order to compute target kills, the spacing within vehicles is required to be computed for each unit. The value of attribute (8) is decreased by the value represented by the number of companies within each unit times the average interval (37.5 meters) between units. This value is then divided by the total number of vehicles in that unit and converted to feet. MISSILE then uses a looping structure to simulate firing from one to three missiles. For each loop passage, a random sample drawn from the uniform (0,1) distribution is assigned to SHOT. Then based on the vehicle interval computed outside the loop, the subroutine tests to see if the vehicle interval was less than or equal to 120 feet or greater than 120 feet. The variable SHOT is then tested within the appropriate branch and the number of kills is assigned to the variable NUMKIL. NUMKIL is incremented for each missile shot. MISSILE returns to event 12 the number of kills and the delay time imposed. The number of vehicle kills is subtracted from attribute (3) and the event time is incremented by the delay time. If the number of armored vehicles is less than zero, attribute (4) (wheeled vehicles) is decreased by this amount to model the correct number of kills. The head entity exits the event and is filed on the event calendar. Once the event calendar schedules it again, the delay time has transpired and it travels to AWAIT node MAF, with duration equal to attribute (10).

The lower portion of event 12 contains the conditional statements for the tail entity. Its values for attributes three and 16 must be adjusted to correspond to the head entity values. Two variables in the head entity block, VAL1 and DELCH1, are assigned the head's values for attributes 16 and three. These variables are then assigned to the tail entity's attributes three and 16. Additionally, attribute (16) is increased by the separation distance between the head and tail. This is accomplished by dividing attribute (8) by the rate. Once this is accomplished, the tail entity exits the event and is filed on the event calendar. When it appears again on the event calendar, it travels to AWAIT node MAF, with duration equal to attribute (10).

AWAIT node MAF stores convoy one in file two while unit one waits for GATE BLOK1 to open. SLAM's concept for a gate is as its name implies. A GATE is either opened or closed and either allows or denies passage, respectively. In this model, the initial gate status for BLOK1 is closed as denoted in the GATE block to the left of EVT1. This SLAM structure shows that BLOK1 is initially closed to model that the main body will not stop or slow up to allow interdicted units to re-enter between units of the main body. This action is modeled in this fashion because allowing the interdicted unit to re-enter would cause congestion on the main body or a slowing down that might present a better target owing to units' interval decrease. The ranking of file two is based on low value first of attribute two. This implies that the head entity is filed before the tail entity. Opening BLOK1 is modeled by the tail entity of the last unit, unit 15. The exit end of EV17 shows the top conditional branch being reserved only for the tail entity of unit 15, the last unit in the main body. The structure at STR1 is an OPEN node that opens BLOK1. This action models the tail entity of 15 clearing the road junction for the blocked unit to enter. No interval distance is modeled between units 15 and one to denote that unit one enters immediately behind 15. The bottom branch exiting EV17 is

AD-A139 495 STOPEM: A SIMULATION INTERDICTION MODEL OF A MOTORIZED RIFLE DIVISION(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING 2/3

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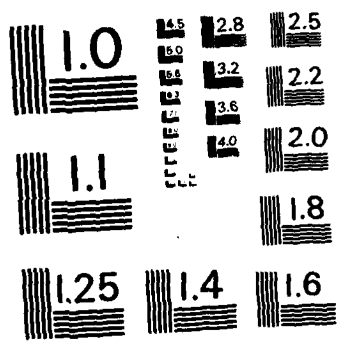

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

taken by all units, including the head of 15 and unit one. The units then maintain this order and finish with unit one last. The remainder of the network for BLUE is as described in the steady state case.

Route GREEN is similar to BLUE because an AWAIT node EKF is also modeled there. Both routes, even if just interdicted once, cause convoys to meet at some future point or take a much longer bypass to prevent this meeting. This particular portion of the road network creates disruption and bunching of units. Even though the road network is seemingly infinite, interdicting these two routes shows an instance where convoy disruption can be maximized.

STOPEM only does one interdiction of the head element of the reconnaissance unit. An examination of the effects of interdiction for this road network on the main body would create more lucrative targets for WAAM targeting, with increased probabilities of destruction.

On the other hand, Route RED is an autobahn that if interdicted offers the possibility for quick exiting and entering again at some future point. Route RED models that the reconnaissance element is interdicted and the main body exits and bypasses the obstacle. As on the other two routes, interdiction occurs and damage and delay are assessed. However, instead of waiting while the main body gets back on the main route, unit one exits the route prior to the point where the main body enters. Event node 36 represents unit one's exit and event node 38 models the main body's entry back onto the original route. The difference between Routes BLUE and GREEN, and Route RED is that there are more likely exit points on RED heading in the original direction of travel that do not cause bunching as opposed to the restrictions on BLUE and GREEN.

Summary

The entire MRD broken down into 44 units with associated attributes is initialized into file one. Once in the file, SLAM enter and event nodes schedule the entry of convoys through the road network. Each convoy is modeled as two entities with unique attributes except for attribute two. This attribute denotes whether the entity is the head or tail element. The indicator variable XX(10) denotes steady state when set equal to zero and interdiction when set equal to one. The flexibility of the model is given by event nodes where user-written subroutines model changes of state for the system. When XX(10) is set equal to one, interdiction occurs in selected event nodes on each route. Within this event, subroutines SORTIE and MISSILE are called to determine interdiction effects. At the conclusion of each convoy arrival at the event node for that route, data is collected for analysis by calling subroutine GAFMGF.

The above concludes Chapter III and how model computerization was accomplished. Chapter IV is next with an explanation of validation and verification.

IV Model Verification and Validation

The model verification and validation process is an important and necessary area to which the modeler must subject the model if he expects to have an acceptable level of confidence in the inferences drawn about the model outputs of the system. This chapter will discuss the process of verification and validation used for STOPEM.

Shannon in Systems Simulation divides the process of evaluating simulations into three categories:

1. verification - insuring that the model behaves the way an experimenter intended.

2. validation - testing the agreement between the behavior of the model and that of the real system.

3. problem analysis - the drawing of statistically significant inferences from the data generated by the computer simulation (51:30).

Chapter VI will discuss the problem analysis, while the remainder of this chapter will discuss the first two points.

Verification

Two categories of tests were performed to verify the internal consistency of the model. The first involved statistical testing of distributions to determine their behavior in the model. The second category of testing consisted of using the SLAM trace option, print statements, and data sent to tapes to verify that the model and its activities were performing as desired.

Sortie and Missile Distributions. Appendix E contains the SPSS output on testing of the Uniform (0,1) distribution used in SORTIE and MISSILE. The null hypothesis tested using a Kolmogorov-Smirnov test was that the samples generated came from the distribution indicated. The null hypothesis failed to be rejected.

Triangular Distributions. No statistical testing was conducted on the triangular distributions. The idea used to develop the distribution was based on the low and high values given in the references cited. A mode value was computed from these values and sampling conducted during the simulations. Checks made throughout model development using the SLAM trace option, explained next, showed that the values obtained were within the specified ranges.

Trace Monitoring. Utilizing SLAM's trace option and print statements throughout the program allowed each entity and four other attributes to be followed from event to event. Since the trace option also showed TNOW and duration to next event, checks were made to determine if entities were arriving at their next point at the appointed time. This option also gave the terminate time for each entity. By knowing when a unit entered the system and when it arrived at its destination, finish time data was checked for accuracy. Print statements such as shown in Appendix E also gave feedback if interdiction subroutines were working as modeled. In all cases checked, the model was functioning as intended.

Validation

Three possible tests exist for examining model validity. The first is face validity. This test consists of checking the model at extreme values for parameters and examining for the reasonableness of results. The latter method is referred to as a Turing test. This test consists of using experts to examine model outputs to compare these outputs against the actual system. The other two methods consist of "testing of assumptions" and "the testing of input-output transformations" (Ref 51:29). These last two methods are concerned with statistically related testing for such things as tests of means and variances and analysis of variance (51:29). STOPEM's validation process consisted of a combination of the first and the last of the above tests. The usage of these tests in STOPEM's validation is one of degree, as will be discussed after an explanation for the purpose of the model is made.

STOPEM represents an abstraction of the real system. To balance the reality of the system under study with the limitations of time, resources such as computer availability, and tractability of the model, assumptions discussed in previous chapters were made to formulate STOPEM as it is now. To simulate the complete system under study would require a model of such complexity that the required time to exercise it would consume incalculable resources and time. As an abstraction, STOPEM represents a portion of the system with those variables perceived to be more important, that when acted upon by external forces, present insights about the system and its interactions, if any. The validation of STOPEM must be evaluated with this in mind.

Variation of the parameters for the triangular distributions was not conducted at the extreme values. However, a ten percent reduction in the mode parameters for the convoy rate, length, and interval was made. These variations will be discussed further in Chapter V. The results given based on these variations proved to be consistent. Results will be discussed in Chapter VI. The subroutines SORTIE and MISSILE contain concepts of the contributions of air sorties and missile strikes. The modeling of air sortie results in the program in Appendix B and the discussion of the reasonableness of these results with informed experts gave credibility to the parameter used in determining when the road was cut or partially blocked. The effects of a missile attack was hypothesized based on information received from Fort Sill, Oklahoma. The generic missile postulated and the effects gave consistent results. Finally, tbe uniform (0,1) distribution used in MISSILE and SORTIE was tested as discussed in the verification portion of this chapter. All the above combined give STOPEM validity.

Once the model verification and validation is complete, testing of the system can begin. This chapter has explained how the model was verified and validated. Chapter V discusses the data collection and how the experiment was conducted.

V Data Collection

In order to draw meaningful inferences about the system under study once the model has been verified and validated, an experimental design is needed to run the model to obtain the data necessary to make an analysis (51:145). Designs of experiments have two purposes: "(1) they are economical in terms of reducing the number of experimental trials required; and (2) they provide a structure for the investigator's learning process" (Ref 51:145). This chapter discusses how the experiment was designed to obtain the required data.

Measure of Effectiveness (MOE)

In this thesis, a MRD consisting of 44 units was put through the system in each simulation run. A measure of effectiveness (MOE) was developed to use as a standard to compare model outputs. The MOE developed is the arrival rate per hour of armored vehicles of the MRD at its destination. This MOE was selected as a way to measure the arriving combat power, represented by armored vehicles, because one objective of this thesis was to determine how the arrival of combat systems can be affected by interdiction. The more the MRD can be delayed, disrupted, or destroyed, the less the impact on the friendly force at the MRD point of commitment. The design of the experiment, which follows next, relates how the model experimentation will be conducted to determine the MOE or response variable.

Experimental Design

Shannon in Systems Simulation describes experimental design as a systematic three-way process. The three steps are: "(1) design of the structural model; (2) design of the functional model; and (3) design of the experimental model" (Ref 51:151). The structural model and the functional differ in that the former presents what should be done in terms of factors and factor levels to be analyzed, while the latter says what can be done. This difference is attributed to constraints such as computer time or funds that might require a reduction of factors or levels in the experimental design. This redesign becomes the functional model. A definition follows for factors, levels, and cells in the context used above and in the remainder of this research. A factor is an independent variable being examined, while the factor level refers to a factor value. Table 5.1 presents the factors and associated levels analyzed. These will be discussed further in subsequent paragraphs. A cell refers to the "basic structure or building block of an experiment" (Ref 51:153).

Equation 5.1 was used to determine the structural model:

$$N_s = (q_1)(q_2)(q_3)\ldots(q_k) \qquad (5.1)$$

TABLE 5.1

Factors and Levels to be Analyzed in the Experiment

Factor	Level 1	Level 2	Level 3	Level 4
Interdiction Policy	none	1/1	1/2	1/3
Convoy Rate	(20,25,30)	(20,22.5,30)		
Convoy Interval	(20,25,30) recon units (3,4,5) all other units	(20,22.5,30) recon units (3,3.6,5) all other units		
Convoy Length	(as original initialization for level one; 10% reduction for each mode parameter for each convoy - see INTLC in program)			

where

N_s = number of cells in the experiment

k = number of factors in the experiment

q_i = number of levels of ith factor, $i=1,2,3,\ldots k$

(Ref 51:153)

Based on this formula, the structural model for this experiment is (4)(2)(2)(2) = 32 cells. Because computer time was not a constraint and the model run time was not excessive, each cell had a response. This makes the functional model a complete model as opposed to an incomplete model that has fewer responses than the number of cells.

Sample size determination for each cell or the number of replications per cell was based on what is considered adequate. An adequate number of replications per cell is eight (Ref 51:163). To determine where the response variable mean would lie based on this number of replications, Eq (5.2) was used to make a calculation to determine this.

$$n = \frac{(\sigma Z_{\frac{\alpha}{2}})^2}{d^2} \tag{5.2}$$

where

n = number of runs

σ = population standard deviation

$Z_{\frac{\alpha}{2}}$ = two-tailed standardized normal statistic

α = alpha level

d = allowable error

Using $\alpha = 0.05$, $n = 8$, and $d = \frac{\sigma}{x}$, the above equation gave that the response for the sample mean would lie between $\mu \pm 0.70$, where μ is the unknown true population mean. This implies that using eight replications per cell gives a 95 percent probability that the interval $\mu \pm 0.70$ contains the sample mean for the response variable.

In order to capture the model response due to the variation of these four factors and their associated levels, a full factorial design was run. A full factorial design implies that "all levels of a given factor are combined with all levels of every other factor in the experiment" (51:164). This design allows for the study of the factor main effects as well as interactions between factors if they exist. Interactions refer to both the individual influence of a factor and the combined influence of two or more factors on the response variable. Also, since the effect of each factor is estimated at several levels of the other factors, "the conclusions reached hold over a wide range of conditions" (51:165).

The factors and the levels used in this experiment were structured into logical patterns so that the necessary observations could be made. As previously mentioned, Table 5.1 contains the factors and levels. The subsequent paragraphs explain in more detail the factors and levels.

Factor one, the interdiction policy, was set at four levels to denote no interdiction and the combination of one sortie plus either one, two, or three missiles. These four levels represent four possible interdiction policies, with increasing number of missiles denoting increased need for destruction and delay or a higher priority target.

Convoy rate, the second factor, was set at two levels: sample from a triangular distribution (20,25,30) and sample from another triangular distribution (20,22.5,30). The first rate represents the distribution with the mode as the average of the minimum and maximum rates, whereas the second represents a -ten percent shift in the mode to represent a partial decrease due to such effects as road damage and weather.

The third factor, convoy length, was also considered at two levels: the first level represents the length as drawn from another triangular distribution with the parameters left as computed in the initialization subroutine. The second level represents a -ten percent decrease in the mode parameter for each entity. This represents the decrease in convoy length due to mechanical vehicle losses or prior interdiction.

The fourth factor, convoy interval, represents the distance in kilometers between convoys. As with the other factors, the first level represents the initial computation of parameters, while the second level represents decreased convoy interval.

Table 5.2 is the design matrix for the blocks of runs. As this table shows, a total of 256 simulation runs were made. These 256 runs were divided into blocks of 64 runs, where there were 8 cells within each block, and 8 replications per block, for a total of 64.

TABLE 5.2

Design Matrix for Block of Simulation Runs

Run Number	Policy
1-64	One (No interdiction)
65-128	Two
129-192	Three
193-256	Four

Table 5.3 shows how each block from Table 5.2 was designed. This table shows that runs one through eight represent the first cell with all factors set at level one. The second set of runs, nine through 16, show that all the factor levels remain the same except that the interval now is at level two. This same process continues for the other six cells. For runs 65 through 128, 129 through 192, and 193 through 256, Table 5.3 would be the same, except that the levels for the policy would be two, three, and four, respectively.

TABLE 5.3

Design Matrix Within Each Block

Run	Factors			
	Policy	Rate	Length	Interval
1-8	1	1	1	1
9-16	1	1	1	2
17-24	1	1	2	1
25-32	1	1	2	2
33-40	1	2	1	1
41-48	1	2	1	2
49-56	1	2	2	1
57-64	1	2	2	2

The experiment was run once the measure of effectiveness, the appropriate sample size, and the experimental design were determined. The analysis of this data is presented in Chapter VI.

VI Data Analysis

The next step after gathering data from the experimental design is to conduct an analysis of the data. This part of the analysis process allows the analyst to make valid inferences relative to the model's output. Analysis of variance (ANOVA) using the Statistical Package for the Social Sciences (SPSS) is an available tool to test hypotheses to determine if several populations' means are equal. ANOVA provides the analyst with a capability to determine if response variable means are equal based on the factors and levels. The analyst can then make inferences about the model outputs.

Both four-way and three-way ANOVAs were conducted on the data generated by the design of experiment discussed in Chapter V. The terms three-way and four-way refer to three and four factors in the experiment. Both ANOVAs were also conducted with all second and higher order interactions suppressed. This implies that these ANOVA tables presented in Appendix C do not have interaction effects present. The interactions were suppressed to gain further insights about the main effect contributions since all second and higher order interactions proved to be insignificant. Appendix C contains all SPSS outputs and tape 1, which is the actual data. A discussion follows of the results.

Three-Way and Four-Way ANOVAs

Both ANOVAs with interactions showed that only two of the main effects were significant using an alpha level of 0.05. All two-way and higher interactions proved to be insignificant at this same alpha level. The factor length was deleted to make the three-way ANOVA. The reason for its deletion was based upon it having the lowest value of significance based on the four-way ANOVA with interactions. The lower F value pointed to its contributing less to explaining the main effects. The ANOVAs without interactions show the same two main effects being significant. In order to gain a more robust representation of the statistical contributions of the main effects, a selection was made from the two ANOVAs without interactions of the one with the lowest mean square error. The model thus selected would tend to explain more about the main effects. The four-way ANOVA proved to have the lowest mean square error. This is reasonable considering that all factors, in spite of two being insignificant, make for a more complete system representation since the convoy length and convoy interval represent key parts of the system.

Main Effects. Main effects refers to each independent variable or factor. The SPSS output in Appendix C shows that only two of the four main effects were considered statistically significant at the alpha level of 0.05. This says that, at the stated alpha level, the mean value for the response variable is statistically different for different levels of the factors of policy and rate. To graphically illustrate that this statistical difference does exist, a plot is made with the main effects and their associated levels along the horizontal axis and the response variable along the vertical axis. The lines drawn between points only serve to emphasize changes in the response variables due to factor levels and do not represent linear relationships. As the plots in Figure 6.1 show, the change in slope in policy and rate indicate that a difference does exist between levels of these two factors. In contrast, the other two factors show relatively no change in slope and hence show no statistical differences. This implies that, for the given levels, the two factors do not have any significant impact on the response variable.

Main effects behave as expected. As policy level one shows, no interdiction allows a rate of arrival of approximately 80 armored vehicles per hour at the destination point. The interdiction effects show up as the steep change in slope of Figure 6.1 when going from no interdiction to one sortie and one missile. Policies two, three, and four show no appreciable difference. As would be expected, policy four was a combination of one sortie and three missiles and it has the lowest vehicle arrival rate. A bigger difference between policies two, three, and four might have been expected if the main body of the convoy had been interdicted also. The other factor, convoy rate, shows a drop in vehicle arrival rate as the rate is decreased ten percent. This is again consistent with what would be expected because a reduced convoy rate means units arrive at the destination later. The other two main effects, while not significant, also show consistency. As the length and interval go from level one to two, the arrival rate increases. Since level two is a ten percent decrease in the convoy length and interval, the units are neither as long nor is the distance to travel between them as far. This implies that a lesser distance takes less time to travel, so the arrival rate increases.

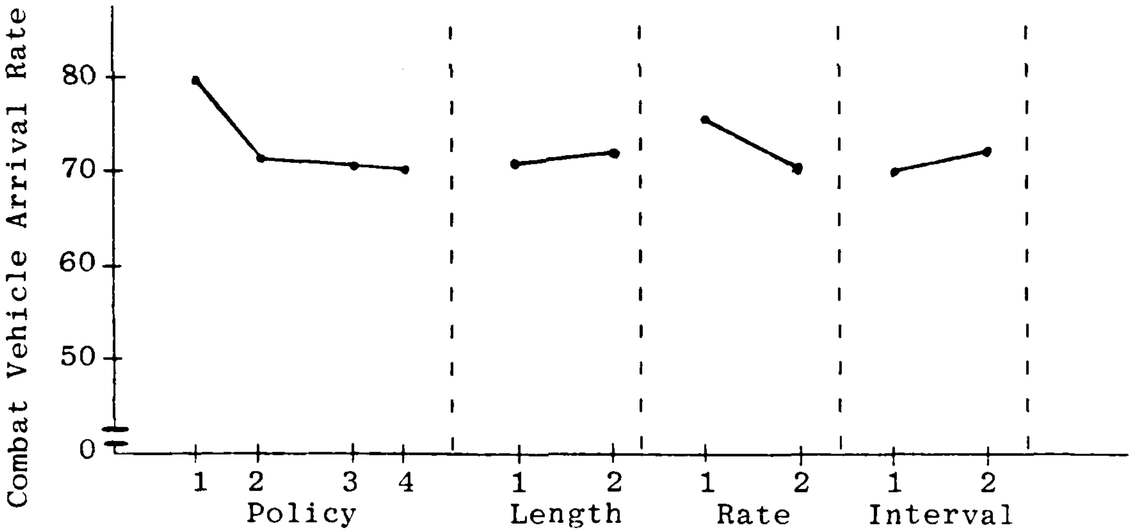

Fig 6.1. Influence of Main Effects

<u>Two-Way and Higher Interactions</u>. As the SPSS print-out in Appendix C shows, there are no significant two-way or higher interactions. An explanation offered for this lack

of interactions is the measure of effectiveness (MOE) variable. Since the MOE has time as part of its measure, it is likely that the rate and policy factors dominate the other two or that the amount of variation (ten percent reduction) was not sufficient to get a bigger change in the response variable for length and interval. A sensitivity analysis conducted at the extreme values for these factors might provide some additional insights into how the model is working. Another possible explanation for this lack of two-way interactions and that an almost significant three-way interaction of length, rate, and interval was close to the 0.05 cutoff, is that the equal variance assumption between cells might have been violated. A test for equality of variance, which was not conducted, might show that this is the case. Since the number of replications per cell, eight, was not large enough to invoke the central limit theorem (CLT), the replications per cell would have to increase to meet CLT criteria of 30 or greater per cell. The CLT says that as the number of replications approaches infinity the random variable response approaches normality (Ref 51:187). Since the above are explanations that were not tested, they are offered as suggestions for follow-on work or checking of the model outputs.

This chapter has explained the data analysis of the experiment. Chapter VII presents the Results and Conclusions.

VII Conclusions and Recommendations and Recommendations for Follow-on Study

This thesis modeled a motorized rifle division (MRD), represented by 44 units, moving through a hypothesized three-route network. The experimentation consisted of comparing the steady state of the system, that is no interdiction, against the three policies of interdiction, consisting of combinations of sorties and missiles. The measure of effectiveness was the arrival rate of armored vehicles. The analysis consisted of a four-way ANOVA conducted on the data generated by the levels of the four factors. This chapter presents the conclusions and recommendations and recommendations for follow-on study.

Conclusions and Recommendations

The objective of this thesis, as stated in Chapter I, was to develop a model of a MRD moving through a road network to determine how interdiction would delay the MRD combat power arrival rate into a portion of a corps sector. The conclusions are as follows:

1. Interdiction of just one element on each route does cause delay, disruption, and destruction of the MRD.

2. The difference in increased levels of missile usage did not appreciably show a significant decrease in the combat arrival rate as Figure 6.1 shows. This result is attributed to the targeting of only reconnaissance units since the rerouting of the main body onto a different route to bypass the interdicted point did not

add appreciable delay time to the MRD. This is due in part to a road network that permits relative ease of bypassing the interdicted point.

3. Modeling the interdiction of roads and convoys by conventional munitions is a difficult task that requires close coordination between the Army and the Air Force.

Based on the above conclusions, the following recommendations are made:

1. That the model be enhanced further to include interdiction of the main body to gain insights into further decreasing the combat power arrival rate.

2. That efforts to improve coordination between the Air Force and the Army continue to insure the greatest effect of employment of limited resources against the second-echelon threat.

Recommendations for Follow-on Study

Since this research effort could not address all aspects of the system studied or provide insights to all the questions that need to be asked, some areas are recommended for thought or follow-on study concerning second-echelon interdiction.

As was explained, STOPEM assumed a hypothesized route for the MRD. Developing a model that would determine shortest route distance based on time to travel would provide ideas on which routes would be more likely travel routes. Such a model would necessitate a decision structure that would incorporate type of road (autobahn, primary, secondary, or tertiary); the load carrying capacity of any bridges along that route that would limit route to vehicles less than a certain weight classification; a route that would facilitate convoy passage (whether a winding road, hilly, numerous defiles); road interdiction potential; and the number of built-up areas to traverse.

The effect of interdiction and convoy passage will degrade the road quality over time. As time into the conflict increases, convoy rates would decrease as a result. The hypothesized triangular distribution for the rate then might better be represented by a mode that is closer to the low value parameter instead of the average of the low and high values.

This model assumes that the head element of the convoy is always interdicted. This process needs to be modified to include the stochasticity of when and where the sortie and convoy would actually meet at the point of interdiction. The model assumes perfect intelligence to say that existing technology and new technology will facilitate target acquisition. Also, sortie generation is considered constant, with no modeling of the FEBA penetration.

One aspect not incorporated is the refugee problem and how it would affect the movement of both combat forces and the logistical effort. Until the refugee problem subsides, it can be expected to have a lowering effect on convoy movement rates.

Development of an interactive program to model real time movement of convoys would provide a valuable training tool for training of corps and division staff elements in the process of getting a feel for how rapidly second-echelon forces will close the gap from detection to commitment. Such a program would show the importance of getting timely intelligence, processing it, deciding whether or not to target, ordering the mission, executing the mission, and analyzing the result. Such a model might show that incoming data could easily overwhelm the information processors, and thus delay the order to interdict, resulting in a missed opportunity. This overwhelming of the processors would be due to the amount of incoming information and the arrival rate of this data.

Since the Warsaw Pact Armies are expected to consume prodigious quantities of both petroleum products and ammunition with their rates of advance and reliance on firepower, an indirect approach to getting at this one weakness might be to examine what the required rates are to maintain this momentum and how interdiction of these factors would affect the capability to fight or sustain an offensive.

STOPEM assumes that echelonment of forces is taking place. While the technique of echelonment is not characteristic in all attack scenarios, attack without echelonment would mean a dispersal of forces along a wider frontage. Intelligence nets, processing of information, and decision making would be deluged with inputs. This would make it difficult to stop the attacking forces conventionally because the enemy force density would be fairly uniform, arriving at the FEBA simultaneously. However, this might raise the U.S. nuclear threshold because of presented target densities. This might also increase the case for more and more lethal wide area weapons to stop this wide attack. One key point here is: do not assume away the possibility of an attack on a wide frontage if Warsaw Pact intention is to overwhelm a dispersed defense and prevent lateral shifting of forces. Also, if the Warsaw Pact perceives NATO's reluctance to use nuclear weapons, the Warsaw Pact could use high speed roads such as autobahns to double up convoys abreast and get units to the front faster. Without nuclear weapons, conventional forces would be strained to stop such rapid movement. As before, such a movement tactic could be countered with WAAM type weapons. The point of all this is that any studies done need to remain cognizant that echelonment and dispersal are not fixed doctrine because circumstance could dictate exceptions to what is considered normal operating procedure.

STOPEM assumes that the interval between vehicles and units varies between 25 and 50 meters. A study to determine Warsaw Pact equipment operator driving habits and how they affect intervals and march discipline might provide some interesting insights of how accurate estimates are. One would expect that little or no previous driving experience of the average Warsaw Pact soldier would mean stricter compliance with intervals. The contrast with the western counterpart who has more driving experience and thus carries bad habits (failure to maintain interval) with him when operating military vehicles while in convoy would probably show that the Warsaw Pact armies have better march discipline. This characteristic might make it harder to create vehicle bunching.

The areas mentioned in this chapter are considerations for further study with STOPEM or as separate efforts. Some are related directly and others indirectly since second-echelon interdiction is a small subsystem of a much larger and complex system. The ideas presented in this chapter were meant as much to stimulate thought as well as possibly provide ideas for enhancement of STOPEM or creation of new models or studies.

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APPENDIX A

SLAM COMPUTER MODEL

The computer model starts on the next page and is divided into three parts: (1) job control cards; (2) the SLAM coded portion; and (3) the FORTRAN coded portion. The SLAM portion has an explanation of the global variables and the attributes. The FORTRAN coded portion has comment cards at strategic points to further clarify. The user is cautioned about numbering of enter nodes. SLAM is limited to 25 enter nodes. Thus, any enter nodes numbered greater than 25 will result in a SLAM input error. A way to get around this, as this model shows, is to number any enter nodes with the beginning numbers of the network, that is all network enter nodes are numbered one through eight.

```
CAF,CM165000,T400,I0400.  T820389,FULTON,4258
ATTACH,PROCFIL,ID=AR10171,SN=ASDAD.
BEGIN,NOSFILE.
ATTACH,PROCFIL,SLAMPROC,ID=AFIT.
GET,THE22,ID=FULTON.
GET,TUS22,ID=FULTON.
FTN5(I=TUS22,ANSI=0).
BEGIN,SLAMII,,I=THE22,M=LGO.
EXIT,U.
REWIND,TAPE11.
REWIND,TAPE15.
REWIND,TAPE19.
REWIND,TAPE23.
REPLACE,TAPE11,ID=FULTON.
REPLACE,TAPE15,ID=FULTON.
REPLACE,TAPE19,ID=FULTON.
REPLACE,TAPE23,ID=FULTON.
*
*
*
*
*
*
*
GEN,G.A. FULTON,STOPEM,03/10/83,256;
LIMITS,3,14,300;
PRIORITY/1,LVF(1);(INITIAL FILE WITH 44 ENTITIES)
PRIORITY/2,LVF(2);(AWAIT NODE BLOK1)
PRIORITY/3,LVF(2);(AWAIT NODE BLOK2)
NETWORK;
;
;
;***********************************************************************
;
;  DESCRIPTION OF KEY GLOBAL VARIABLES AND ATTRIBUTES FOLLOW. EACH OF
;  THE THREE ROAD NETWORKS IS OUTLINED BELOW. INITIALLY,ATTRIBUTES
;  9 AND 10 ARE READ INTO FILE ONE. SUBSEQUENT VALUES FOR ATTRIBUTE 9 & 10 ARE
;  RECOMPUTED DUE TO RATE CHANGE IN SUBROUTINE EVENT.  GATES BLOK1 & BLOK2
;  ARE INITIALLY CLOSED TO DENOTE THAT THE MAIN BODY HAS PRIORITY AT A ROAD
;  JUNCTION & THAT THE UNIT ENTERING HAS TO WAIT.
;
;***********************************************************************
;
;
;     XX(1)=COUNTER TO ACCESS ATTRIBUTES FILE1(ENTITIES 1-15)
;     XX(2)=COUNTER TO ACCESS ATTRIBUTES FILE1(ENTITIES 16-31)
;     XX(3)=COUNTER TO ACCESS ATTRIBUTES FILE1(ENTITIES 32-44)
;     XX(4)=VARIABLE FOR TESTING RATE,RESHUF1
;     XX(5)=VARIABLE FOR TESTING RATE,RESHUF2
;     XX(6)=VARIABLE FOR TESTING RATE,RESHUF3
```

```
;      XX(7)=NUMBER OF SORTIES
;      XX(8)=NUMBER OF MISSILES
;      XX(9)=COUNTER IN SORTIE FOR NUMBER OF KILLS
;      XX(10)=VARIABLE TO INDICATE WHETHER OR NOT INTERDICTION(0--NO;1--YES)
;      XX(11)=COUNTER FOR NUMBER OF MISSILES SHOT(1,2,OR,3)
;      XX(12)=VARIABLE TO INDICATE THAT EVENT 12 HAS OCCURRED
;             (0--NO;1--YES),INITIALIZED TO 0.0 IN INTLC
;      XX(13)=VARIABLE TO INDICATE THAT EVENT 23 HAS OCCURRED
;             (0--NO;1--YES),INITIALIZED TO 0.0 IN INTLC
;      XX(14)=VARIABLE TO INDICATE THAT EVENT 34 HAS OCCURRED
;             (0--NO;1--YES),INITIALIZED TO 0.0 IN INTLC
;      XX(15)=VARIABLE TO ADJUST MODE PARAMETER IN CONVOY LENGTH
;             DISTRIBUTION(0--NONE;0.1--10% REDUCTION)
;      XX(16)=VARIABLE TO ADJUST MODE PARAMETER IN CONVOY RATE
;             DISTRIBUTION(25.0--REGULAR;22.5--10% REDUCTION)
;      XX(17)=VARIABLE TO ADJUST MODE PARAMETER IN CONVOY INTERVAL
;             DISTRIBUTION--RECON UNITS ONLY(UNITS 1,16,32)
;             (25.0--REGULAR;22.5--10% REDUCTION)
;      XX(18)=VARIABLE TO ADJUST MODE PARAMETER IN CONVOY INTERVAL
;             DISTRIBUTIONS--ALL OTHER UNITS
;             (4.0--REGULAR;3.6--10% REDUCTION)
;      XX(19)=TIME OF FINISH FOR CONVOYS ROUTE # 1
;      XX(20)=TIME OF FINISH FOR CONVOYS ROUTE # 2
;      XX(21)=TIME OF FINISH FOR CONVOYS ROUTE # 3
;      XX(22)=(XX(19)+XX(20)+XX(21))/3--TIME OF TRAVEL MRD
;      XX(23)=ARMORED VEHICLES FINISHED ROUTE # 1
;      XX(24)=ARMORED VEHICLES FINISHED ROUTE # 2
;      XX(25)=ARMORED VEHICLES FINISHED ROUTE # 3
;      XX(26)=XX(23)+XX(24)+XX(25)--TOTAL ARMORED VEHICLES FINISHED
;      XX(27)=MEASURE OF MERIT--NUMBER OF ARMORED VEHICLES ARRIVED AT
;             TERMINATION POINT PER HOUR--XX(26)/XX(22)
;      XX(28)=COUNTER USED IN OUTPUT SUBROUTINE GAFMGF
;      ATRIB(1)=UNIT TYPE
;      ATRIB(2): 1=HEAD OF CONVOY, 2=TAIL OF CONVOY
;      ATRIB(3)=NO. OF TRACK VEHICLES
;      ATRIB(4)=NO. OF WHEEL VEHICLES
;      ATRIB(5)=MIN UNIT LENGTH (KM)
;      ATRIB(6)=MAX UNIT LENGTH (KM)
;      ATRIB(7)=AVG UNIT LENGTH (KM)--(ATRIB(5)+ATRIB(6)/2)
;      ATRIB(8)=UNIT LENGTH,SAMPLE FROM TRIANGULAR DIST (KM)
;      ATRIB(9)=TRAVEL TIME FOR 1ST NODE (DISTANCE/ATRIB(11)--HRS)
;      ATRIB(10)= TRAVEL TIME SUBSEQUENT NODES (DISTANCE/ATRIB(11)--HRS)
;      ATRIB(11)=DAY RATE,MIXED CONVOY,SAMPLE FROM TRIANGULAR DIST (KM/HR)
;      ATRIB(12)=INTERVAL LENGTH,SAMPLE FROM TRIANGULAR DIST (KM)
;      ATRIB(13)=TIME ENTITY STARTS (TNOW)
;      ATRIB(14)=TIME ENTITY FINISHES (TNOW-ATRIB(13))
;      ATRIB(15)=ASSIGNED BY SLAM AS MAX NUMBER OF ATTRIBUTES(14)+1,
;                AS EVENT CODE
;      ATRIB(16)=ASSIGNED BY SLAM AS MAX NUMBER OF ATTRIBUTES(14)+2,
;                EVENT TIME
```

```
;
;
;ROUTE BLUE(ENTITIES 1-15)
;
        GATE/BLOK1,CLOSE,2;
        GATE/BLOK2,CLOSE,3;
;
EVT1    EVENT,1,1;
ACT2    ACT,,,GO1;
ENT1    ENTER,2,1;
        ACT,,,GO1;
ENT2    ENTER,3,1;
ACT1    ACT/1,,,GO1;
ENT8    ENTER,8,1;(NOT USED)
        ACT,ATRIB(10),,MAF;
GO1     GOON,1;
ACT3    ACT/2,ATRIB(9);
EV11    EVENT,11,1;
ACT4    ACT/3,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.1.0,EV14;
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).EQ.1.0,EV12;
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GT.1.0,EV13;
EV12    EVENT,12,1;
        ACT/4,ATRIB(10),,MAF;
MAF     AWAIT(2),BLOK1,1;
        ACT/5,,,EV17;
EV13    EVENT,13,1;
        ACT/6;
EV14    EVENT,14,1;
        ACT/7,ATRIB(10);
EV15    EVENT,15,1;
        ACT,ATRIB(10);
EV16    EVENT,16,1;
        ACT,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.1.0,EV18;
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GT.1.0,EV17;
EV17    EVENT,17,1;
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).EQ.15.0.AND.
            ATRIB(2).EQ.2.0,STR1;
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).LE.15.0,EV18;
STR1    OPEN,BLOK1,1;
        ACT,,,EV18;
EV18    EVENT,18,1;
        ACT,ATRIB(10);
;
;
;***********************************************************************
;
;  HEAD OF THE CONVOY BYPASSES COLLECT NODE. THIS NODE
;  ONLY INTERESTED IN TAIL TIME FINISH OF EACH ENTITY AND THEN
;  LAST UNIT FINISH TIME.
;
```

```
;*********************************************************************
;
;
EV19   EVENT,19,1;
ACT5   ACT,,ATRIB(2).EQ.1.0,GOE;
ACT6   ACT;
COL1   COLCT,INT(13),UNIT TIME RT#1;
       ACT;
CO1    COLCT,ATRIB(3),ARMORED VEHICLES;
       ACT,,,GOE;
;
;
;ROUTE GREEN(ENTITIES 16-31)
;
;
EV20   EVENT,20,1;
       ACT,,,GO11;
ENT4   ENTER,4,1;
       ACT,,,GO11;
ENT5   ENTER,5,1;
       ACT/8,,,GO11;
ENT9   ENTER,9,1;(NOT USED)
       ACT,,,EKF;
GO11   GOON,1;
       ACT/9,ATRIB(9);
EV21   EVENT,21,1;
       ACT/10,ATRIB(10);
EV22   EVENT,22,1;
       ACT/11,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.16.0,EV25;
       ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).EQ.16.0,EV23;
       ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GT.16.0,EV24;
EV23   EVENT,23,1;
       ACT/12,ATRIB(10),,EKF;
EKF    AWAIT(3),BLOK2,1;
       ACT/13,,,EV26;
EV24   EVENT,24,1;
       ACT/14,,,EV25;
EV25   EVENT,25,1;
       ACT/15;
EV26   EVENT,26,1;
       ACT,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.16.0,EV28;
       ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).EQ.31.0.AND.
           ATRIB(2).EQ.2.0,STR2;
       ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GE.16.0,EV27;
STR2   OPEN,BLOK2,1;
       ACT,,,EV28;
EV27   EVENT,27,1;
       ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GE.16.0,EV28;
EV28   EVENT,28,1;
       ACT/16,ATRIB(10);
```

```
EV29  EVENT,29,1;
      ACT,ATRIB(10);
EV30  EVENT,30,1;
      ACT,ATRIB(10);
;
;
;**********************************************************************
;
;  HEAD OF THE CONVOY BYPASSES COLLECT NODE. THIS NODE
;  ONLY INTERESTED IN TAIL TIME FINISH OF EACH ENTITY AND THEN
;  THE LAST UNIT FINISH TIME.
;
;**********************************************************************
;
;
EV31  EVENT,31,1;
      ACT,,ATRIB(2).EQ.1.0,GOE;
      ACT;
COL2  COLCT,INT(13),UNIT TIME RT#2;
      ACT;
CO2   COLCT,ATRIB(3),ARMORED VEHICLES;
      ACT,,,GOE;
;
;
;ROUTE RED(ENTITIES 32-44)
;
;
EV32  EVENT,32,1;
      ACT,,,GO21;


ENT6  ENTER,6,1;
      ACT,,,GO21;
ENT7  ENTER,7,1;
      ACT/17,,,GO21;
EN10  ENTER,10,1;(NOT USED)
      ACT,,,GO30;
GO21  GOON,1;
      ACT/18,ATRIB(9);
EV33  EVENT,33,1;
      ACT,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.32.0,EV36;
      ACT,,ATRIB(1).EQ.32.0.AND.XX(10).EQ.1.0,EV34;
      ACT,ATRIB(10),ATRIB(1).GT.32.0.AND.XX(10).EQ.1.0,EV35;
EV34  EVENT,34,1;
      ACT,,,GO30;
GO30  GOON,1;
      ACT,ATRIB(10),,EV36;
EV35  EVENT,35,1;
      ACT;
EV36  EVENT,36,1;
      ACT,ATRIB(10),XX(10).EQ.0.0.AND.ATRIB(1).GE.32.0,EV37;
      ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).GT.32.0,EV38;
```

```
        ACT,ATRIB(10),XX(10).EQ.1.0.AND.ATRIB(1).EQ.32.0,EV39;
EV37    EVENT,37,1;
        ACT/19,ATRIB(10);
EV38    EVENT,38,1;
        ACT/20,ATRIB(10),,EV40;
EV39    EVENT,39,1;
        ACT/21,ATRIB(10),,EV40;
;
;
;*************************************************************************
;
;  HEAD OF THE CONVOY BYPASSES COLLECT NODE. THIS NODE
;  ONLY INTERESTED IN TAIL TIME FINISH OF EACH ENTITY AND THEN
;  THE LAST UNIT FINISH TIME.
;
;*************************************************************************
;
;
EV40    EVENT,40,1;
        ACT,,ATRIB(2).EQ.1.0,GOE;
        ACT;
COL3    COLCT,INT(13),UNIT TIME PT#3;
        ACT;
CO3     COLCT,ATRIB(3),ARMORED VEHICLES;
        ACT,,,GOE;
;
;
;
;
GOE     GOON,1;
TE      TERM;
        END;
INIT,0,150;
;
;  START OF 256 SIMULATION RUNS, DONE IN BLOCKS OF
;  8, RANDOM NUMBER SEEDS REINITIALIZED AT START OF
;  EACH BLOCK OF 64 RUNS.
;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.0,XX(16)=25.0,XX(17)=25.0,
        XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.0,XX(16)=25.0,XX(17)=22.5,
```

```
     XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.0,XX(16)=22.5,XX(17)=25.0,
     XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.0,XX(16)=22.5,XX(17)=22.5,
     XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.1,XX(16)=25.0,XX(17)=25.0,
     XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.1,XX(16)=25.0,XX(17)=22.5,
     XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
```

```
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.1,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=0.0,XX(11)=0.0,XX(15)=0.1,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
;
;  2ND BLOCK OF 64 RUNS STARTS HERE.
;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.0,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.0,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
```

```
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.0,XX(16)=22.5,XX(17)=25.0
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.0,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.1,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.1,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.1,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
```

```
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=1.0,XX(15)=0.1,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
;
;  3RD BLOCK OF 64 RUNS STARTS HERE.
;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.0,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.0,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.0,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
```

```
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.0,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.1,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.1,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.1,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=2.0,XX(15)=0.1,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
```

```
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
;
;  4TH BLOCK OF 64 RUNS STARTS HERE.
;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.0,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.0,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.0,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.0,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
```

```
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.1,XX(16)=25.0,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.1,XX(16)=25.0,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.1,XX(16)=22.5,XX(17)=25.0,
      XX(18)=4.0;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
INTLC,XX(10)=1.0,XX(11)=3.0,XX(15)=0.1,XX(16)=22.5,XX(17)=22.5,
      XX(18)=3.6;
SEEDS;
SIMULATE;
SIMULATE;
SIMULATE;
SIMILATE;
SIMULATE;
SIMULATE;
SIMULATE;
SIMULATE;
FIN;
```

```
*
*
*
*
*
*
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,TAPE15)
      DIMENSION NSET(10000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON QSET(10000)
      EQUIVALENCE (NSET(1),QSET(1))
      NCRDR=5
      NPRNT=6
      NTAPE=7
      NNSET=10000
      CALL SLAM
      STOP
      END
*
*
***********************************************************************
*
*     VALUES USED THROUGH OUT THE PROGRAM ARE INITIALIZED AND READ INTO
*     FILE ONE,WHERE THE RANKING IS BASED ON THE LOW VALUE
*     OF ATRIBUTE 1,THE UNIT DESIGNATION.
*
***********************************************************************
*
*
      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
      SAVE/UCOM1/
      DIMENSION A(20),B(20),C(20)
      REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
      INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
      DATA A,B,C/20*0.0,20*0.0,20*0.0/
      DIF1=0.0
      DIF2=0.0
      DIF3=0.0
      XX(1)=1
      XX(2)=16
```

```
      XX(3)=32
      XX(4)=0.0
      XX(5)=0.0
      XX(6)=0.0
      XX(7)=30.0
      XX(8)=100.0
      XX(12)=0.0
      XX(13)=0.0
      XX(14)=0.0
      XX(19)=0.0
      XX(20)=0.0
      XX(21)=0.0
      XX(22)=0.0
      XX(23)=0.0
      XX(24)=0.0
      XX(25)=0.0
      XX(26)=0.0
      XX(27)=0.0
      XX(28)=0.0
*
*
************************************************************************
*
*     ROUTE BLUE (ENTITIES 1-15). ATRIBUTES 1-12 FOR ENTITIES 1-15 ARE
*     READ INTO FILE ONE. ATRIBUTE ONE IS THE UNIT NUMBER. OTHER
*     ATRIBUTES ARE EXPLAINED IN THE SLAM CODED PORTION OF THE MODEL ABOVE.
*
************************************************************************
*
*
      A(1)=1
      A(2)=1.0
      A(3)=57
      A(4)=32
      A(5)=2.4
      A(6)=4.8
      A(7)=3.6-XX(15)*3.6
      A(8)=TRIAG(A(5),A(7),A(6),4)
      A(11)=TRIAG(20.0,XX(16),30.0,1)
      A(12)=TRIAG(20.0,XX(17),30.0,3)
      A(9)=64.784/A(11)
      A(10)=14.864/A(11)
      CALL FILEM(1,A)
      A(1)=2
      A(2)=1.0
      A(3)=5
      A(4)=25
      A(5)=0.75
      A(6)=1.5
      A(7)=1.125-XX(15)*1.125
```

```
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=3
A(2)=1.0
A(3)=28
A(4)=2
A(5)=0.9
A(6)=1.8
A(7)=1.35-XX(15)*1.35
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=4
A(2)=1.0
A(3)=33
A(4)=9
A(5)=1.1
A(6)=2.2
A(7)=1.65-XX(15)*1.65
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=5
A(2)=1.0
A(3)=30
A(4)=9
A(5)=1.0
A(6)=2.0
A(7)=1.5-XX(15)*1.5
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=6
A(2)=1.0
A(3)=7
A(4)=89
A(5)=2.5
```

```
A(6)=5.0
A(7)=3.75-XX(15)*3.75
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=7
A(2)=1.0
A(3)=51
A(4)=2
A(5)=1.4
A(6)=2.8
A(7)=2.1-XX(15)*2.1
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=8
A(2)=1.0
A(3)=5
A(4)=30
A(5)=0.875
A(6)=1.75
A(7)=1.3125-XX(15)*1.3125
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=9
A(2)=1.0
A(3)=0
A(4)=15
A(5)=0.4
A(6)=0.8
A(7)=0.6-XX(15)*0.6
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=10
A(2)=1.0
A(3)=0
```

```
A(4)=59
A(5)=1.6
A(6)=3.2
A(7)=2.4-XX(15)*2.4
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=11
A(2)=1.0
A(3)=0
A(4)=59
A(5)=1.6
A(6)=3.2
A(7)=2.4-XX(15)*2.4
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=12
A(2)=1.0
A(3)=0
A(4)=18
A(5)=0.5
A(6)=1.0
A(7)=0.75-XX(15)*0.75
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=13
A(2)=1.0
A(3)=0
A(4)=71
A(5)=1.9
A(6)=3.8
A(7)=2.85-XX(15)*2.85
A(8)=TRIAG(A(5),A(7),A(6),4)
A(11)=TRIAG(20.0,XX(16),30.0,1)
A(12)=TRIAG(3.0,XX(18),5.0,3)
A(9)=64.784/A(11)
A(10)=14.864/A(11)
CALL FILEM(1,A)
A(1)=14
```

```
      A(2)=1.0
      A(3)=0
      A(4)=48
      A(5)=1.3
      A(6)=2.6
      A(7)=1.95-XX(15)*1.95
      A(8)=TRIAG(A(5),A(7),A(6),4)
      A(11)=TRIAG(20.0,XX(16),30.0,1)
      A(12)=TRIAG(3.0,XX(18),5.0,3)
      A(9)=64.784/A(11)
      A(10)=14.864/A(11)
      CALL FILEM(1,A)
      A(1)=15
      A(2)=1.0
      A(3)=0
      A(4)=202
      A(5)=5.1
      A(6)=10.2
      A(7)=7.65-XX(15)*7.65
      A(8)=TRIAG(A(5),A(7),A(6),4)
      A(11)=TRIAG(20.0,XX(16),30.0,1)
      A(12)=TRIAG(3.0,XX(18),5.0,3)
      A(9)=64.784/A(11)
      A(10)=14.864/A(11)
      CALL FILEM(1,A)
*
*
************************************************************************
*
*     ROUTE GREEN (ENTITIES 16-31). ATRIBUTES 1-12 FOR ENTITIES 16-31 ARE
*     READ INTO FILE ONE. ATRIBUTE ONE THE UNIT NUMBER. OTHER
*     ATRIBUTES ARE EXPLAINED IN THE SLAM CODED PORTION OF THE MODEL ABOVE.
*
************************************************************************
*
*
      B(1)=16
      B(2)=1.0
      B(3)=57
      B(4)=32
      B(5)=2.4
      B(6)=4.8
      B(7)=3.6-XX(15)*3.6
      B(8)=TRIAG(B(5),B(7),B(6),4)
      B(11)=TRIAG(20.0,XX(16),30.0,1)
      B(12)=TRIAG(20.0,XX(17),30.0,3)
      B(9)=64.972/B(11)
      B(10)=7.628/B(11)
      CALL FILEM(1,B)
      B(1)=17
```

```
B(2)=1.0
B(3)=5
B(4)=25
B(5)=0.75
B(6)=1.5
B(7)=1.125-XX(15)*1.125
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=18
B(2)=1.0
B(3)=28
B(4)=2
B(5)=0.9
B(6)=1.8
B(7)=1.35-XX(15)*1.35
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=19
B(2)=1.0
B(3)=33
B(4)=9
B(5)=1.1
B(6)=2.2
B(7)=1.65-XX(15)*1.65
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=20
B(2)=1.0
B(3)=30
B(4)=9
B(5)=1.0
B(6)=2.0
B(7)=1.5-XX(15)*1.5
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
```

```
CALL FILEM(1,B)
B(1)=21
B(2)=1.0
B(3)=7
B(4)=89
B(5)=2.5
B(6)=5.0
B(7)=3.75-XX(15)*3.75
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=22
B(2)=1.0
B(3)=0
B(4)=59
B(5)=1.6
B(6)=3.2
B(7)=2.4-XX(15)*2.4
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=23
B(2)=1.0
B(3)=0
B(4)=57
B(5)=1.5
B(6)=3.0
B(7)=2.25-XX(15)*2.25
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=24
B(2)=1.0
B(3)=0
B(4)=56
B(5)=1.5
B(6)=3.0
B(7)=2.25-XX(15)*2.25
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
```

```
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=25
B(2)=1.0
B(3)=22
B(4)=76
B(5)=2.5
B(6)=5.0
B(7)=3.75-XX(15)*3.75
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=26
B(2)=1.0
B(3)=0
B(4)=56
B(5)=1.5
B(6)=3.0
B(7)=2.25-XX(15)*2.25
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=27
B(2)=1.0
B(3)=0
B(4)=66
B(5)=1.8
B(6)=3.6
B(7)=2.7-XX(15)*2.7
B(8)=TRIAG(B(5),B(7),B(6),4)
B(11)=TRIAG(20.0,XX(16),30.0,1)
B(12)=TRIAG(3.0,XX(18),5.0,3)
B(9)=64.972/B(11)
B(10)=7.628/B(11)
CALL FILEM(1,B)
B(1)=28
B(2)=1.0
B(3)=0
B(4)=40
B(5)=1.1
B(6)=2.2
B(7)=1.65-XX(15)*1.65
B(8)=TRIAG(B(5),B(7),B(6),4)
```

```
      B(11)=TRIAG(20.0,XX(16),30.0,1)
      B(12)=TRIAG(3.0,XX(18),5.0,3)
      B(9)=64.972/B(11)
      B(10)=7.628/B(11)
      CALL FILEM(1,B)
      B(1)=29
      B(2)=1.0
      B(3)=5
      B(4)=60
      B(5)=1.7
      B(6)=3.4
      B(7)=2.55-XX(15)*2.55
      B(8)=TRIAG(B(5),B(7),B(6),4)
      B(11)=TRIAG(20.0,XX(16),30.0,1)
      B(12)=TRIAG(3.0,XX(18),5.0,3)
      B(9)=64.972/B(11)
      B(10)=7.628/B(11)
      CALL FILEM(1,B)
      B(1)=30
      B(2)=1.0
      B(3)=0
      B(4)=18
      B(5)=0.5
      B(6)=1.0
      B(7)=0.75-XX(15)*0.75
      B(8)=TRIAG(B(5),B(7),B(6),4)
      B(11)=TRIAG(20.0,XX(16),30.0,1)
      B(12)=TRIAG(3.0,XX(18),5.0,3)
      B(9)=64.972/B(11)
      B(10)=7.628/B(11)
      CALL FILEM(1,B)
      B(1)=31
      B(2)=1.0
      B(3)=0
      B(4)=31
      B(5)=0.9
      B(6)=1.8
      B(7)=1.35-XX(15)*1.35
      B(8)=TRIAG(B(5),B(7),B(6),4)
      B(11)=TRIAG(20.0,XX(16),30.0,1)
      B(12)=TRIAG(3.0,XX(18),5.0,3)
      B(9)=64.972/B(11)
      B(10)=7.628/B(11)
      CALL FILEM(1,B)
*
*
*****************************************************************
*
*     ROUTE RED (ENTITIES 32-44). ATRIBUTES 1-12 FOR ENTITIES 32-44 ARE
*     READ INTO FILE ONE. ATRIBUTE ONE IS THE UNIT NUMBER. OTHER
```

```
*      ATRIBUTES ARE EXPLAINED IN THE SLAM CODED PRIORTION OF THE MODEL ABOVE.
*
*****************************************************************
*
*
       C( 1)=37
       C(2)=1.0
       C(3)=5
       C(4)=30
       C(5)=0.875
       C(6)=1.75
       C(7)=1.3125-XX(15)*1.3125
       C(8)=TRIAG(C(5),C(7),C(6),4)
       C( 11)=TRIAG(20.0,XX( 16),30.0,1)
       C( 12)=TRIAG(3.0,XX( 18),5.0,3)
       C(9)=56.628/C( 11)
       C( 10)=11.616/C( 11)
       CALL FILEM( 1,C)
       C( 1)=32
       C(2)=1.0
       C(3)=39
       C(4)=8
       C(5)=1.5
       C(6)=3.0
       C(7)=2.25-XX( 15)*2.25
       C(8)=TRIAG(C(5),C(7),C(6),4)
       C( 11)=TRIAG(20.0,XX( 16),30.0,1)
       C( 12)=TRIAG(20.0,XX( 17),30.0,3)
       C(9)=56.628/C( 11)
       C( 10)=11.616/C( 11)
       CALL FILEM( 1,C)
       C( 1)=33
       C(2)=1.0
       C(3)=6
       C(4)=10
       C(5)=0.5
       C(6)=1.0
       C(7)=0.75-XX( 15)*0.75
       C(8)=TRIAG(C(5),C(7),C(6),4)
       C( 11)=TRIAG(20.0,XX( 16
```

```
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=34
C(2)=1.0
C(3)=33
C(4)=0
C(5)=1.0
C(6)=2.0
C(7)=1.5-XX(15)*1.5
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=35
C(2)=1.0
C(3)=23
C(4)=0
C(5)=0.7
C(6)=1.7
C(7)=1.2-XX(15)*1.2
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=36
C(2)=1.0
C(3)=15
C(4)=89
C(5)=2.6
C(6)=5.2
C(7)=3.9-XX(15)*3.9
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=38
C(2)=1.0
C(3)=0
C(4)=18
C(5)=0.5
C(6)=1.0
C(7)=0.75-XX(15)*0.75
```

```
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=39
C(2)=1.0
C(3)=57
C(4)=32
C(5)=2.4
C(6)=4.8
C(7)=3.6-XX(15)*3.6
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=40
C(2)=1.0
C(3)=5
C(4)=25
C(5)=0.75
C(6)=1.5
C(7)=1.125-XX(15)*1.125
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=41
C(2)=1.0
C(3)=28
C(4)=2
C(5)=0.9
C(6)=1.8
C(7)=1.35-XX(15)*1.35
C(8)=TRIAG(C(5),C(7),C(6),4)
C(11)=TRIAG(20.0,XX(16),30.0,1)
C(12)=TRIAG(3.0,XX(18),5.0,3)
C(9)=56.628/C(11)
C(10)=11.616/C(11)
CALL FILEM(1,C)
C(1)=42
C(2)=1.0
C(3)=33
C(4)=9
C(5)=1.1
```

```
      C(6)=2.2
      C(7)=1.65-XX(15)*1.65
      C(8)=TRIAG(C(5),C(7),C(6),4)
      C(11)=TRIAG(20.0,XX(16),30.0,1)
      C(12)=TRIAG(3.0,XX(18),5.0,3)
      C(9)=56.628/C(11)
      C(10)=11.616/C(11)
      CALL FILEM(1,C)
      C(1)=43
      C(2)=1.0
      C(3)=23
      C(4)=9
      C(5)=1.8
      C(6)=1.6
      C(7)=1.2-XX(15)*1.2
      C(8)=TRIAG(C(5),C(7),C(6),4)
      C(11)=TRIAG(20.0,XX(16),30.0,1)
      C(12)=TRIAG(3.0,XX(18),5.0,3)
      C(9)=56.628/C(11)
      C(10)=11.616/C(11)
      CALL FILEM(1,C)
      C(1)=44
      C(2)=1.0
      C(3)=14
      C(4)=124
      C(5)=3.7
      C(6)=7.4
      C(7)=5.55-XX(15)*5.55
      C(8)=TRIAG(C(5),C(7),C(6),4)
      C(11)=TRIAG(20.0,XX(16),30.0,1)
      C(12)=TRIAG(3.0,XX(18),5.0,3)
      C(9)=56.628/C(11)
      C(10)=11.616/C(11)
      CALL FILEM(1,C)
*
*
*****************************************************************
*
*     NETWORK PASSAGE IS INITIATED BY CALLING THE EVENT NODE
*     AT THE START OF EACH ROAD NETWORK.
*
*****************************************************************
*
*
      CALL SCHDL(1,0.0,ATRIB)
      CALL SCHDL(20,0.0,ATRIB)
      CALL SCHDL(32,0.0,ATRIB)
      RETURN
      END
*
```

```
*
*
*
      SUBROUTINE EVENT(IN)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
      SAVE/UCOM1/
      REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
      INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,NSHOT
      POLICY=XX(10)
      GO TO(100,200,300,400,500,600,700,800,900,1000,1100,1200,1300,
     + 1400,1500,1600,1700,1800,1900,2000,2100,2200,2300,2400,
     + 2500,2600,2700,2800,2900,3000,3100,3200,3300,3400,3500,3600,3700,
     + 3800,3900,4000),IN
*
*
***********************************************************************
*
*     ROUTE BLUE (ENTITIES 1-15). FIRST EVENT NODE STARTS THE SCHEDULING
*     OF THE CONVOYS. THE HEAD & TAIL OF THE CONVOY ARE SCHEDULED TO COME
*     INTO THE NETWORK WITH THE ENTER NODES 2 & 3 AT THE TIME THAT ALLOWS FOR
*     PASSAGE OF THE VEHICLES IN BETWEEN THE HEAD AND TAIL. SUBSEQUENT EVENTS
*     RECOMPUTE ATRIBUTE 10,THE  TIME THROUGH THE NEXT NODES.
*     END TIME IS COMPUTED AND SENT TO TAPE  IN EVENT 19.
*     WHEN ATRIBUTE 2 VALUE IS 2,THIS REPRESENTS THE TAIL OF THE
*     CONVOY. WHEN THE VALUE OF ATRIBUTE 2 IS 1(HEAD),IT BYPASSES
*     THE LAST EVENT IN THE APPROPRIATE ROAD SEGMENT.
*
***********************************************************************
*
*
 100  IF(XX(1).LE.15.0)THEN
      I1=INT(XX(1))
      CALL COPY(I1,1,ATRIB)
*
* CONVOY RATE IS ADJUSTED.
*
      CALL RESHUF1
      IF(XX(10).EQ.1.0)THEN
         ATRIB(9)=50.0/ATRIB(11)
      ENDIF
      IF(I1.EQ.1)THEN
         TIME=TNOW
         ATRIB(13)=TNOW
```

```
*
* SCHEDULE HEAD OF CONVOY 1
*
            CALL SCHDL(2,TIME,ATRIB)
         ENDIF
         ATRIB(2)=2.0
*
* REINITIALIZE ATTRIBUTE(9) DUE TO RATE CHANGE
*
         IF(XX(10).EQ.0.0)THEN
            ATRIB(9)=64.784/ATRIB(11)
         ENDIF
         CINT1=ATRIB(12)
         ATRIB(13)=TNOW
         TIME=ATRIB(8)/ATRIB(11)
*
* SCHEDULE TAIL ENTITY
*
         CALL SCHDL(3,TIME,ATRIB)
         IF(I1.EQ.15)GO TO 150
         I1=I1+1
         CALL COPY(I1,1,ATRIB)
         CALL RESHUF1
*
* RATE ADJUSTMENT
*
         IF(XX(10).EQ.1.0)THEN
            ATRIB(9)=50.0/ATRIB(11)
         ENDIF
         TIME=(TIME+(CINT1/ATRIB(11)))
         IF(XX(10).EQ.0.0)THEN
            ATRIB(9)=64.784/ATRIB(11)
         ENDIF
*
* SCHEDULE HEAD ENTITY OF NEXT CONVOY
*
         CALL SCHDL(2,TIME,ATRIB)
         ATRIB(13)=TIME
*
* RESCHEDULE EVENT #1 TO CONTINUE PROCESS
*
         CALL SCHDL(1,TIME,ATRIB)
  150    XX(1)=XX(1)+1
         ENDIF
         RETURN
  200    CALL ENTER(2,ATRIB)
         RETURN
  300    CALL ENTER(3,ATRIB)
         RETURN
  800    CALL ENTER(8,ATRIB)
```

```
      RETURN
 1100 IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.1.0))THEN
         ATRIB(10)=14.864/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.1.0))THEN
         ATRIB(10)=14.784/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.1.0))THEN
         ATRIB(10)=29.90/ATRIB(11)
      ENDIF
      RETURN
*
* INTERDICTION OF CONVOY #1,HEAD ELEMENT
*
 1200 IF((ATRIB(1).EQ.1.0).AND.(ATRIB(2).EQ.1.0).AND.
    + (XX(10).EQ.1).AND.(XX(12).EQ.0.0))THEN
         CALL SORTIE
         IF(XX(9).EQ.0.0)THEN
*
* 2 KILLS SUBTRACTED OUT & EVENT TIME ADJUSTED
*
            ATRIB(3)=ATRIB(3)-2
            ATRIB(16)=ATRIB(16)+DTIMEP/60.0
         ELSE
*
* 2 KILLS SUBTRACTED OUT & EVENT TIME ADJUSTED
*
            ATRIB(3)=ATRIB(3)-2
            ATRIB(16)=ATRIB(16)+DTIME/60.0
         ENDIF
         CALL MISSILE
         IF(NUMKIL.LE.5)THEN
            DTMIS1=DTMIS1/60.0 + 0.0
*
* ADJUST ATTRIBUTE(3) CONVOY LENGTH CORRECTION INCLUDES
* KILLS FROM SORTIE,AVERAGE INTERVAL BETWEEN VEHICLES
* ASSUMED(25+50/2=37.5). CONVERSION MADE TO KM.
* SAME APPLIES FOR TWO ELSE STATEMENTS BELOW.
* EVENT TIME IS ADJUSTED DUE DELAY.
*
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH1=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS1
            ATRIB(10)=23.897/ATRIB(11)
            XX(12)=1.0
            VAL1=ATRIB(16)
         ELSE IF(NUMKIL.LE.10)THEN
            DTMIS2=DTMIS2/60.0+0.0
```

```
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH1=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS2
            ATRIB(10)=23.897/ATRIB(11)
            XX(12)=1.0
            VAL1=ATRIB(16)
         ELSE
            DTMIS3=DTMIS3/60.0+0.0
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH1=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS3
            ATRIB(10)=23.897/ATRIB(11)
            XX(12)=1.0
            VAL1=ATRIB(16)
         ENDIF
*
* TAIL OF CONVOY #1 RESCHDULED WITH NEW EVENT TIME.
*
*
      ELSE IF((ATRIB(1).EQ.1.0).AND.(ATRIB(2).EQ.2.0).AND.
     + (XX(10).EQ.1.0).AND.(XX(12).EQ.1.0))THEN
         ATRIB(16)=(ATRIB(8)/ATRIB(11))+VAL1
         ATRIB(3)=DELCH1
         ATRIB(10)=23.987/ATRIB(11)
      ENDIF
      RETURN
 1300  ATRIB(10)=4.0/ATRIB(11)
      RETURN
 1400  ATRIB(10)=3.88/ATRIB(11)
      RETURN
 1500  ATRIB(10)=1.824/ATRIB(11)
      RETURN
 1600 IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.1.0))THEN
         ATRIB(10)=7.24/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.1.0))THEN
         ATRIB(10)=4.74/ATRIB(11)
      ENDIF
      RETURN
 1700 IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.1.0))THEN
         ATRIB(10)=2.5/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.1.0).AND.
     + (ATRIB(2).EQ.1.0))THEN
         TWAIT2=FFAWT(2)
         ATRIB(10)=2.5/ATRIB(11)
```

```
      ELSE IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.1.0).AND.
     + (ATRIB(2).EQ.2.0))THEN
         TWAIT2=FFAWT(2)
         ATRIB(10)=(2.5+ATRIB(8))/ATRIB(11)
      ENDIF
      RETURN
 1800 ATRIB(10)=12.92/ATRIB(11)
      RETURN
*
* UPDATE ARMOR VEHICLES TOTAL,ONLY TAIL OF CONVOY
* EXITS HERE. THIS EVENT TAIL TIME ELEMENT IS
* RECORDED AND GAFMGF CALL IF LAST ELEMENT.
* THIS IS LAST OF  "IF" BLOCKS THAT DENOTES ORDER OF
* FINISH FOR LAST UNIT IS DEPENDENT ON
* WHETHER INTERDICTION OR NOT.
*
 1900 IF(ATRIB(2).EQ.2.0)THEN
         ATRIB(14)=TNOW-ATRIB(13)
      IF(NNRUN.EQ.1)THEN
         WRIT(5,'(3I4,3F8.2)')1,NNRUN,POLICY,ATRIB(3),ATRIB(1),
     +   ATRIB(14)
      ENDIF
      XX(23)=XX(23)+ATRIB(3)
      IF((ATRIB(1).EQ.15.0).AND.(XX(10).EQ.0.0))THEN
         XX(28)=XX(28)+1


         XX(19)=XX(19)+TNOW
         CALL GAFMGF
      ENDIF
      IF((ATRIB(1).EQ.1.0).AND.(XX(10).EQ.1.0))THEN
         XX(28)=XX(28)+1
         XX(19)=XX(19)+TNOW
         CALL GAFMGF
      ENDIF
      ENDIF
      RETURN
*
*
**********************************************************************
*
*     ROUTE GREEN (ENTITIES 16-31). EXPLANATION IS THE SAME AS GIVEN
*     ABOVE. HOWEVER,EVENT 20,AND ENTER NODES 4 & 5 FULFILL THE ABOVE ROLES
*     OF 1,2, AND 3,RESPECTIVELY. COMMENTS ABOVE APPLY TO SIMILIAR AREAS IN
*     IN GREEN BELOW.
*
**********************************************************************
*
*
 2000 IF(XX(2).LE.31.0)THEN
      J1=INT(XX(2))
      CALL COPY(J1,1,ATRIB)
```

```
      CALL RESHUF2
      IF(J1.EQ.16)THEN
         TIME2=TNOW
         ATRIB(13)=TNOW
         CALL SCHDL(4,TIME2,ATRIB)
      ENDIF
      ATRIB(2)=2.0
      TIME2=ATRIB(8)/ATRIB(11)
      CINT2=ATRIB(12)
      ATRIB(9)=64.972/ATRIB(11)
      ATRIB(13)=TNOW
      CALL SCHDL(5,TIME2,ATRIB)
      IF(J1.EQ.31)GO TO 2050
      J1=J1+1
      CALL COPY(J1,1,ATRIB)
      CALL RESHUF2
      TIME2=(TIME2+(CINT2/ATRIB(11)))
      ATRIB(9)=64.972/ATRIB(11)
      CALL SCHDL(4,TIME2,ATRIB)
      ATRIB(13)=TIME2
      CALL SCHDL(20,TIME2,ATRIB)
2050  XX(2)=XX(2)+1
      ENDIF
      RETURN
400   CALL ENTER(4,ATRIB)
      RETURN
500   CALL ENTER(5,ATRIB)
      RETURN
900   CALL ENTER(9,ATRIB)
      RETURN
2100  ATRIB(10)=7.628/ATRIB(11)
      RETURN
2200  IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.16.0))THEN
         ATRIB(10)=2.7/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.16.0))THEN
         ATRIB(10)=2.7/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.16.0))THEN
         ATRIB(10)=17.42/ATRIB(11)
      ENDIF
      RETURN
*
* INTERDICTION OF UNIT #16. SEE EVENT 12 ABOVE
* SAME THOUGHT PROCESS APPLIES HERE AS ABOVE,
* WITH NUMBER OF CONVOY AS EXCEPTION.
*
2300  IF((ATRIB(1).EQ.16.0).AND.(ATRIB(2).EQ.1.0).AND.
     + (XX(10).EQ.1).AND.(XX(13).EQ.0.0))THEN
         CALL SORTIE
```

```
      IF(XX(9).EQ.0.0)THEN
         ATRIB(3)=ATRIB(3)-2
         ATRIB(16)=ATRIB(16)+DTIMEP/60.0
      ELSE
         ATRIB(3)=ATRIB(3)-2
         ATRIB(16)=ATRIB(16)+DTIME/60.0
      ENDIF
      CALL MISSILE
      IF(NUMKIL.LE.5)THEN
         DTMIS1=DTMIS1/60.0 + 0.0
         ATRIB(3)=ATRIB(3)-NUMKIL
         IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
         ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
         ATRIB(16)=ATRIB(16)+DTMIS1
         ATRIB(10)=10.568/ATRIB(11)
         XX(13)=1.0
         VAL2=ATRIB(16)
      ELSE IF(NUMKIL.LE.10)THEN
         DTMIS2=DTMIS2/60.0+0.0
         ATRIB(3)=ATRIB(3)-NUMKIL
         DELCH2=ATRIB(3)
         IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
         ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
         ATRIB(16)=ATRIB(16)+DTMIS2
         ATRIB(10)=10.568/ATRIB(11)
         XX(13)=1.0
         VAL2=ATRIB(16)
      ELSE
         DTMIS3=DTMIS3/60.0+0.0
         ATRIB(3)=ATRIB(3)-NUMKIL
         DELCH2=ATRIB(3)
         IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
         ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
         ATRIB(16)=ATRIB(16)+DTMIS3
         ATRIB(10)=10.568/ATRIB(11)
         XX(13)=1.0
         VAL2=ATRIB(16)
      ENDIF
   ELSE IF((ATRIB(1).EQ.16.0).AND.(ATRIB(2).EQ.2.0).AND.
  + (XX(10).EQ.1.0).AND.(XX(13).EQ.1.0))THEN
      ATRIB(16)=(ATRIB(8)/ATRIB(11))+VAL2
      ATRIB(3)=DELCH2
      ATRIB(10)=10.568/ATRIB(11)
   ENDIF
   RETURN
2400 RETURN
2500 ATRIB(10)=10.568/ATRIB(11)
   RETURN
2600 IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.16.0))THEN
      ATRIB(10)=5.9/ATRIB(11)
```

```
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.16.0).AND.
     + (ATRIB(2).EQ.1.0))THEN
         TWAIT3=FFAWT(3)
         ATRIB(10)=3.5/ATRIB(11)
      ELSE IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.16.0).AND.
     + (ATRIB(2).EQ.2.0))THEN
         TWAIT3=FFAWT(3)
         ATRIB(10)=(3.5+ATRIB(8))/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.16.0))THEN
         ATRIB(10)=2.4/ATRIB(11)
      ENDIF
      RETURN
 2700 IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.16.0))THEN
         ATRIB(10)=2.016/ATRIB(11)
      ENDIF
      IF((XX(10).EQ.1.0).AND.(ATRIB(1).EQ.16.0))THEN
         ATRIB(10)=2.4/ATRIB(11)
      ENDIF
      RETURN
 2800 ATRIB(10)=1.344/ATRIB(11)
      RETURN
 2900 ATRIB(10)=12.292/ATRIB(11)
      RETURN
 3000 ATRIB(10)=13.628/ATRIB(11)
      RETURN
*
* SEE EVENT 19 ABOVE,SAME THOUGHT APPLIES HERE.
*
 3100 IF(ATRIB(2).EQ.2.0)THEN
         ATRIB(14)=TNOW-ATRIB(13)
      IF(NNRUN.EQ.1)THEN
         WRITE(15,'(3I4,3F8.2)')2,NNRUN,POLICY,ATRIB(3),ATRIB(1),
     +   ATRIB(14)
      ENDIF
      XX(24)=XX(24)+ATRIB(3)
      IF((ATRIB(1).EQ.31.0).AND.(XX(10).EQ.0.0))THEN
         XX(28)=XX(28)+1
         XX(20)=XX(20)+TNOW
         CALL GAFMGF
      ENDIF
      IF((ATRIB(1).EQ.16.0).AND.(XX(10).EQ.1.0))THEN
         XX(28)=XX(28)+1
         XX(20)=XX(20)+TNOW
         CALL GAFMGF
      ENDIF
      ENDIF
      RETURN
*
```

```
*
**************************************************************************
*
*      ROUTE RED (ENTITIES 32-44). EXPLANATION IS THE SAME AS GIVEN ABOVE.
*      HOWEVER,EVENT 32 AND ENTER NODES 6 & 7 FULFILL THE ABOVE ROLES OF
*      1,2,AND 3, RESPECTIVELY. COMMENTS ABOVE IN BLUE APPLY IN RED AS WELL.
*
**************************************************************************
*
*
 3200  IF(XX(3).LE.44.0)THEN
       K1=INT(XX(3))
       CALL COPY(K1,1,ATRIB)
       CALL RESHUF3
       IF(K1.EQ.32)THEN
          TIME4=TNOW
          ATRIB(13)=TNOW
          CALL SCHDL(6,TIME4,ATRIB)
       ENDIF
       ATRIB(2)=2.0
       CINT3=ATRIB(12)
       ATRIB(9)=56.628/ATRIB(11)
       ATRIB(13)=TNOW
       TIME4=ATRIB(8)/ATRIB(11)
       CALL SCHDL(7,TIME4,ATRIB)
       IF(K1.EQ.44)GO TO 3250
       K1=K1+1
       CALL COPY(K1,1,ATRIB)
       CALL RESHUF3
       TIME4=(TIME4+(CINT3/ATRIB(11)))
       ATRIB(9)=56.628/ATRIB(11)
       CALL SCHDL(6,TIME4 ATRIB)
       ATRIB(13)=TIME4
       CALL SCHDL(32,TIME4,ATRIB)
 3250  XX(3)=XX(3)+1
       ENDIF
       RETURN
 600   CALL ENTER(6,ATRIB)
       RETURN
 700   CALL ENTER(7,ATRIB)
       RETURN
 1000  CALL ENTER(10,ATRIB)
       RETURN
 3300  IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.32.0))THEN
          ATRIB(10)=11.616/ATRIB(11)
       ENDIF
       IF((ATRIB(1).EQ.32.0).AND.(XX(10).EQ.1.0))RETURN
       IF((XX(10).EQ.1.0).AND.(ATRIB(1).GT.32.0))THEN
          ATRIB(10)=(21.554+6.048)/ATRIB(11)
       ENDIF
```

```
      RETURN
*
* INTERDICTION OF UNIT #32. SEE EVENT 12 FOR EXPLANATION.
*
 3400  IF((ATRIB(1).EQ.32.0).AND.(ATRIB(2).EQ.1.0).AND.
     + (XX(10).EQ.1).AND.(XX(14).EQ.0.0))THEN
         CALL SORTIE
         IF(XX(9).EQ.0.0)THEN
            ATRIB(3)=ATRIB(3)-2
            ATRIB(16)=ATRIB(16)+DTIMEP/60.0
         ELSE
            ATRIB(3)=ATRIB(3)-2
            ATRIB(16)=ATRIB(16)+DTIME/60.0
         ENDIF
         CALL MISSILE
         IF(NUMKIL.LE.5)THEN
            DTMIS1=DTMIS1/60.0 + 0.0
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH3=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS1
            XX(14)=1.0
            VAL3=ATRIB(16)
         ELSE IF(NUMKIL.LE.10)THEN
            DTMIS2=DTMIS2/60.0+0.0
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH3=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS2
            XX(14)=1.0
            VAL3=ATRIB(16)
         ELSE
            DTMIS3=DTMIS3/60.0+0.0
            ATRIB(3)=ATRIB(3)-NUMKIL
            DELCH3=ATRIB(3)
            IF(ATRIB(3).LT.0)ATRIB(4)=ATRIB(4)+ATRIB(3)
            ATRIB(8)=ATRIB(8)-((NUMKIL*37.5+2*37.5)/1000.0)
            ATRIB(16)=ATRIB(16)+DTMIS3
            XX(14)=1.0
            VAL3=ATRIB(16)
         ENDIF
      ELSE IF((ATRIB(1).EQ.32.0).AND.(ATRIB(2).EQ.2.0).AND.
     + (XX(10).EQ.1.0).AND.(XX(14).EQ.1.0))THEN
         ATRIB(16)=(ATRIB(8)/ATRIB(11))+VAL3
         ATRIB(3)=DELCH3
         THEAD3=ATRIB(16)
      ENDIF
      RETURN
```

```
 3500  RETURN
 3600  IF((XX(10).EQ.0.0).AND.(ATRIB(1).GE.32.0))THEN
          ATRIB(10)=4.0/ATRIB(11)
       ENDIF
       IF((ATRIB(1).EQ.32.0).AND.(XX(10).EQ.1.0))THEN
          ATRIB(10)=3.5/ATRIB(11)
       ENDIF
       IF((ATRIB(1).GT.32.0).AND.(XX(10).EQ.1.0))THEN
          ATRIB(10)=11.72/ATRIB(11)
       ENDIF
       RETURN
 3700  ATRIB(10)=11.72/ATRIB(11)
       RETURN
 3800  ATRIB(10)=10.3/ATRIB(11)
       RETURN
 3900  ATRIB(10)=28.0/ATRIB(11)
       RETURN
*
* SEE EVENT 19 ABOVE,SAME THOUGTH APPLIES.
*
 4000  IF(ATRIB(2).EQ.2.0)THEN
          ATRIB(14)=TNOW-ATRIB(13)
       IF(NNRUN.EQ.1)THEN
          WRITE(15,'(3I4,3F8.2)')3,NNRUN,POLICY,ATRIB(3),ATRIB(1),
     +    ATRIB(14)
       ENDIF
       XX(25)=XX(25)+ATRIB(3)
       IF(ATRIB(1).EQ.44.0)THEN
          XX(28)=XX(28)+1
          XX(21)=XX(21)+TNOW
          CALL CAFMGF
       ENDIF
       ENDIF
       RETURN
       END
*
*
***********************************************************************
*
*      ROUTE BLUE. THE FOLLOWING THREE SUBROUTINES PREVENT UNITS FROM
*      PASSING,EACH OTHER ONCE ON THE ROUTE OF MARCH. THE LEAD UNIT
*      SETS THE COLUMN PACE. OTHER UNIT RATES ARE ADJUSTED DEPENDING
*      ON IF THEIR RATE IS LESS THAN OR EQUAL,OR GREATER THAN THE
*      LEAD UNIT RATE. THIS ASSUMES UNITS MAINTAIN SAME RATE.
*
***********************************************************************
*
*
       SUBROUTINE RESHUF1
       COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
```

```
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
       COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
       SAVE/UCOM1/
       REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
       INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
*
*
*
       IF(ATRIB(1).EQ.1)THEN
          XX(4)=ATRIB(11)
       ELSE IF((ATRIB(1).GT.1).AND.(ATRIB(11).LE.XX(4)))THEN
          DIF1=XX(4)-ATRIB(11)
          ATRIB(11)=ATRIB(11)+DIF1
       ELSE IF((ATRIB(1).GT.1).AND.(ATRIB(11).GT.XX(4)))THEN
          DIF1=ATRIB(11)-XX(4)
          ATRIB(11)=ATRIB(11)-DIF1
       ENDIF
       RETURN
       END
*
*
*ROUTE GREEN
*
*
       SUBROUTINE RESHUF2
       COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
       COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
       SAVE/UCOM1/
       REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
       INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
*
*
*
       IF(ATRIB(1).EQ.16)THEN
          XX(5)=ATRIB(11)
       ELSE IF((ATRIB(1).GT.16).AND.(ATRIB(11).LE.XX(5)))THEN
          DIF2=XX(5)-ATRIB(11)
          ATRIB(11)=ATRIB(11)+DIF2
       ELSE IF((ATRIB(1).GT.16).AND.(ATRIB(11).GT.XX(5)))THEN
```

```
         DIF2=ATRIB(11)-XX(5)
         ATRIB(11)=ATRIB(11)-DIF2
      ENDIF
      RETURN
      END
*
*
*ROUTE RED
*
*
      SUBROUTINE RESHUF3
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
      SAVE/UCOM1/
      REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
      INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
*
*
*
      IF(ATRIB(1).EQ.32)THEN
         XX(6)=ATRIB(11)
      ELSE IF((ATRIB(1).GT.32).AND.(ATRIB(11).LE.XX(6)))THEN
         DIF3=XX(6)-ATRIB(11)
         ATRIB(11)=ATRIB(11)+DIF3
      ELSE IF((ATRIB(1).GT.32).AND.(ATRIB(11).GT.XX(6)))THEN
         DIF3=ATRIB(11)-XX(6)
         ATRIB(11)=ATRIB(11)-DIF3
      ENDIF
      RETURN
      END
*
*
*
*
*
      SUBROUTINE SORTIE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
      SAVE/UCOM1/
      REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
```

```
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
       INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
*
*
*
       XX(9)=0.0
       NUPLAN=XX(7)
       IF(NUPLAN.LE.0.0)THEN
          GO TO 51
       ENDIF
*
* DELAY TIME OMPUTED DEPENDING ON ROAD DAMAGE.
*
       DTIME=TRIAG(30.0,34.0,38.0,5)
       DTIMEP=TRIAG(10.0,12.5,15.0,6)
       DO 50 N=1,2
*
* RANDOM # DRAWN AND TESTED BELOW. IF RN .LE. 0.35
* ROAD IS CUT,OTHERWISE ROAD NOT CUT,PUT PARTIAL BLOCK.
*
          PASS=UNFRM(0.0,1.0,2)
          WRITE(11,'(I4,F8.2)')NNRUN,PASS
          IF(PASS.LE.0.35)THEN
             XX(9)=XX(9)+1
          ELSE
             XX(9)=XX(9)+0.0
          ENDIF
          XX(9)=XX(9)+0.0
 50    CONTINUE
       NUPLAN=NUPLAN - 2
       XX(7)=NUPLAN
 51    RETURN
       END
*
*
*
*
*
       SUBROUTINE MISSILE
       COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
       COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
       SAVE/UCOM1/
       REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
       INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
```

```
     + NUMKIL,NUPLAN,MSHOT
*
*
*
      VINT=0.0
      NUMKIL=0
      NUMISS=XX(8)
      IF(NUMISS.LE.0.0)THEN
         GO TO 76
      ENDIF
*
* DETERMINE DELAY TIME DEPENDING ON LEVEL OF DAMAGE.
*
      DTMIS1=TRIAG(15.0,18.5,25.0,8)
      DTMIS2=TRIAG(22.5,30.0,37.5,9)
      DTMIS3=TRIAG(30.0,41.5,50.0,10)
      MSHOT=XX(11)
*
* VEHICLE INTERVAL COMPUTED FOR EACH UNIT,ADJUSTMENT
* IS MADE FOR INTERVAL BETWEEN COMPANIES(6*37.5 & 4*37.5)
* ONCE AGAIN AN AVERAGE INTERVAL IS USED TO SUBTRACT OUT
* INTERVAL FOR COMPANIES.
*
      IF(ATRIB(1).EQ.1.0)THEN
         VINT=((ATRIB(8)*1000.0-6*37.5)/(ATRIB(3)+ATRIB(4)))/0.3048
      ELSE IF(ATRIB(1).EQ.16.0)THEN
         VINT=((ATRIB(8)*1000.0-6*37.5)/(ATRIB(3)+ATRIB(4)))/0.3048
      ELSE IF(ATRIB(1).EQ.32.0)THEN
         VINT=((ATRIB(8)*1000.0-4*37.5)/(ATRIB(3)+ATRIB(4)))/0.3048
      ENDIF
      DO 75 N=1,MSHOT
*
* RANDOM # DRAWN,DEPENDING ON VEHICLE INTERVAL
* APPROPRIATE BRANCH TAKEN & NUMBER OF KILLS
* COMPUTED.
*
         SHOT=UNFRM(0.0,1.0,7)
         WRITE(11,'(I4,F8.2)')NNRUN,SHOT
         IF(VINT.LE.120.0)THEN
            IF(SHOT.LE.0.1074)THEN
               NUMKIL=NUMKIL+0
            ELSE IF(SHOT.LE.0.1142)THEN
               NUMKIL=NUMKIL+1
            ELSE IF(SHOT.LE.0.1260)THEN
               NUMKIL=NUMKIL+2
            ELSE IF(SHOT.LE.0.1498)THEN
               NUMKIL=NUMKIL+3
            ELSE IF(SHOT.LE.0.1836)THEN
               NUMKIL=NUMKIL+4
            ELSE IF(SHOT.LE.0.2420)THEN
```

```
            NUMKIL=NUMKIL+5
         ELSE IF(SHOT.LE.0.3472)THEN
            NUMKIL=NUMKIL+6
         ELSE IF(SHOT.LE.0.5754)THEN
            NUMKIL=NUMKIL+7
         ELSE
            NUMKIL=NUMKIL+8
         ENDIF
      ELSE
         IF(SHOT.LE.0.1074)THEN
            NUMKIL=NUMKIL+0
         ELSE IF(SHOT.LE.0.1498)THEN
            NUMKIL=NUMKIL+1
         ELSE IF(SHOT.LE.0.2302)THEN
            NUMKIL=NUMKIL+2
         ELSE IF(SHOT.LE.0.4592)THEN
            NUMKIL=NUMKIL+3
         ELSE
            NUMKIL=NUMKIL+4
         ENDIF
      ENDIF
      NUMKIL=NUMKIL+0
 75   CONTINUE
      NUMISS=NUMISS-MSHOT
      XX(8)=NUMISS
 76   RETURN
      END
*
*
*
*
*
      SUBROUTINE GAFMGF
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     + ,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,
     + XX(100)
      COMMON/UCOM1/TIME,TIME1,TIME2,TIME3,TIME4,TIME5,POLICY,ROUTE
     + ,I2,I3,J1,J2,J3,DIF1,DIF2,DIF3,DTIME,DTIMEP,NUMKIL,DTMIS1,
     + DTMIS2,DTMIS3,I,J
      SAVE/UCOM1/
      REAL TIME,TIME1,TIME2,TIME3,TIME4,TIME5,DIF1,DIF2,DIF3,
     + DTIME,DTIMEP,DTMIS1,DTMIS2,DTMIS3,TIMEM
      INTEGER I,I1,I2,I3,J,J1,J2,J3,K,L,M,N,POLICY,ROUTE,
     + NUMKIL,NUPLAN,MSHOT
*
*
*
      IF(ATRIB(1).EQ.15.0)THEN
         XX(22)=XX(22)+XX(19)
         XX(26)=XX(26)+XX(23)
```

```
      ELSE IF(ATRIB(1).EQ.1.0)THEN
         XX(22)=XX(22)+XX(19)
         XX(26)=XX(26)+XX(23)
      ELSE IF(ATRIB(1).EQ.31.0)THEN
         XX(22)=XX(22)+XX(20)
         XX(26)=XX(26)+XX(24)
      ELSE IF(ATRIB(1).EQ.16.0)THEN
         XX(22)=XX(22)+XX(20)
         XX(26)=XX(26)+XX(24)
      ELSE IF(ATRIB(1).EQ.44.0)THEN
         XX(22)=XX(22)+XX(21)
         XX(26)=XX(26)+XX(25)
      ENDIF
      IF(XX(28).EQ.3.0)THEN
         XX(27)=XX(27)+(XX(26)/(XX(22)/3))
*
* APPROPRIATE GLOBAL VARIABLES UPDATED. REASON FOR UNIT
* 15&1,16&31,44 IS THAT 15&1,16&31 FINISH IN DIFFERENT
* ORDER DEPENDING ON WHETHER INTERDICTION OR NOT,
* WHEREAS 44 ALWAYS FINISHES LAST DUE TO 32 NOT BEING
* DELAYED LIKE THE OTHER 2.
*
         WRITE(23,'(2I4,5F8.2)')NNRUN,POLICY,XX(15),XX(16),XX(17),
     +   XX(18),XX(27)
*
* PART OF TAPE USED IN MODEL VERFICATION.
*
         WRITE(19,'(I4)')NNRUN
         WRITE(19,'("FINISH TIMES  ",3F8.2)')XX(19),XX(20),XX(21)
         WRITE(19,'("AVERAGE TIME  ",F8.2)')XX(22)/3
         WRITE(19,'("ARMORED VEHICLES  ",F8.2)')XX(26)
      ENDIF
      RETURN
      END
```

APPENDIX B

SORTIE MODEL

The model presented here was used to get an idea of how to obtain a percentage figure of when the road could be expected to be cut. After 1000 simulated bomb drops, the number obtained was 0.35 for the parameters listed in the program. After obtaining it, experienced personnel were questioned about its appropriateness. Based on the general consensus of those questioned, this number was used as the probability of cutting the road in subroutine SORTIE within STOPEM.

The author gratefully acknowledges the expert assistance of LTC Ivy Cook in the preparation of this model.

```
      PROGRAM COOKEM(INPUT,OUTPUT,TAPE1)
      COMMON/UCOM1/A(4000)
      REAL A,THETA,WR,CEPB,XRND1,YRND1,SIGMAX,SIGMAY,XPRIME1,YPRIME1,
     +XDIST1,YDIST1,XDIST2,YDIST2,XRND2,YRND2,XDPRIM1,YDPRIM1,XDPRIM2,
     +YDPRIM2,XPRIME2,YPRIME2,Y3,K,X1,X2,Y13,Y23,HAFTGTL,HAFTGTW
      INTEGER N,N1,C1,C2,C3,C4,C5
      DATA A/4000*0.0/
      THETA=30.0
      WR=15.0
      CEPB=120.0
      N1=1
      B=0.0
      C1=0
      C2=0
      C3=0
      C4=0
      C5=0
      K=2.0
      Y13=0.0
      Y23=0.0
      XDPRIM1=-30.0
      YDPRIM1=90.0
      HAFTGTL=60.0
      HAFTGTW=25.0
*
* XDPRIM1 & YDRIPM1 ARE THE UPPER LEFT COORDINATES OF THE BOMB
* BOX,CORRESPONDING TO THE 2ND QUADRANT. THE HAFTGTL & HAFTGTW
* ARE THE DIMENSIONS OF HALF OF THE ROAD LENGTH AND WIDTH IN
* FEET. IMSL SUBROUTINE IS CALLED TO GENERATE 4000 RANDOM
* VARIATES USING THE SEED GIVEN BELOW AND PLACING THEM IN
* ARRAY A,DIMENSIONED TO (1,4000). A TRANFORMATION OF
* AXIS IS MADE TO THE NEW COORDINATE SYSTEM, IN RELATION
* TO THE ROAD. CEP FORMULA USED IN THIS FORMULATION WAS
* OBTAINED FROM (REF 10). THE K VALUE REPRESENTS THE
* RATIO OF REP TO DEP, THAT IS THE REP = 5*DEP DUE
* TO THE AIRCRAFT VELOCITY CONTRIBUTING THE GREATEST
* ERROR. THE ANGLE OF ATTACK USED IN THIS RUN WAS 30 DEGREES
* WHICH SAYS THAT THE AIRCRAFT ATTACK 30 DEGREES OFFSET FROM
* THE ROAD AXIS.
*
*
      CALL GGNML(123457.D0,4000,A)
      X1=XDPRIM1*COSD(THETA)-YDPRIM1*SIND(THETA)
      Y1=XDPRIM1*SIND(THETA)+YDPRIM1*COSD(THETA)
      X2=XDPRIM1*COSD(THETA)+YDPRIM1*SIND(THETA)
      Y2=XDPRIM1*SIND(THETA)-YDPRIM1*COSD(THETA)
      SIGMAX=CEPB/(0.6512 + K*0.5640)
      SIGMAY=K*SIGMAX
      A1=(XDPRIM1*2.0)*COSD(THETA)+HAFTGTW
*
```

```
* IF THE ANGLE IS LESS THAN 1,THEN THE NEXT COMPUTATION IS
* BYPASSED BECAUSE THE ARGUMENT BLOWS UP.
*
      IF(ABS(THETA-90.0).LT.1)GO TO 1
      B=(HAFTGTW/XDPRIM1)*TAND(THETA)-HAFTGTL
 1    PRINT*,
      PRINT*,
      PRINT*,'K IS  ',K
      PRINT*,'CEP IS  ',CEPB
      PRINT*,'THETA IS  ',THETA
      PRINT*,'A1  ',A1
      PRINT*,'B  ',B
      PRINT*,'BOMB BOX LENGTH IS  ',180
      PRINT*,'BOMB BOX WIDTH IS  ',60
      PRINT*,'TARGET BOX LENGTH IS  ',2.0*HAFTGTL
      PRINT*,'TARGET BOX WIDTH IS   ',2.0*HAFTGTW
      PRINT*,
      PRINT*,
*
* 1000 BOMB DROPS ARE SIMULATED.
*
      DO 100 N=1,1000
         XRND1=A(N1)*SIGMAX
         N1=N1+1
         YRND1=A(N1)*SIGMAY
         N1=N1+1
         XRND2=A(N1)*SIGMAX
         N1=N1+1
         YRND2=A(N1)*SIGMAY
         N1=N1+1
*
* BOMB DROPS ADJUSTED DUE TO RANDOM IMPACTS.
*
         X2DIST1=X1+XRND2
         X1DIST1=X1+XRND1
         Y2DIST1=Y1+YRND2
         Y1DIST1=Y1+YRND1
         X2DIST2=X2+XRND2
         X1DIST2=X2+XRND1
         Y2DIST2=Y2+YRND2
         Y1DIST2=Y2+YRND1
*
* CHECK MADE TO DETERMINE IMPACT OF BOMBS, TESTED
* AGAINST THE ROAD DIMENSIONS.
*
         IF((X1DIST1.GT.-HAFTGTW).OR.(X1DIST2.LT.A1))THEN
                C1=C1+1
                GO TO 350
         ENDIF
         IF(ABS(THETA).LT.1.0)THEN
```

```
              IF((Y1DIST1.GT.-HAFTGTL).AND.(Y1DIST2.LT.HAFTGTL))THEN
                        Y13=0.0
                        GO TO 300
              ELSE
                        GO TO 350
              ENDIF
         ENDIF
         IF(ABS(THETA-90.0).LT.1)THEN
              PROD1=Y1DIST1-2.0*XDPRIM1
              IF((Y1DIST1.LT.HAFTGTL).AND.(PROD1.GT.-HAFTGTL))THEN
                        C2=C2+1
                        GO TO 100
              ELSE
                        GO TO 350
              ENDIF
         ENDIF
            Y13=Y1DIST1+((Y1DIST2-Y1DIST1)/(X1DIST2-X1DIST1))
     +        *(-HAFTGTW-X1DIST1)
 300                     IF((Y13.GE.B).AND.(Y13.LE.HAFTGTL))THEN
                        C2=C2+1
                        GO TO 100
                        ENDIF
*
* THIS PART REPRESENTS THE SECOND AIRCRAFT ATTEMPT TO
* CUT THE ROAD. PRINT STATEMENTS AND COUNTER VARIABLES ARE USED
* TO KEEP TRACK OF NUMBER OF CUTS AND MISSES.
*
 350     CONTINUE
         IF((X2DIST1.GT.-HAFTGTW).OR.(X2DIST2.LT.A1))THEN
              C3=C3+1
              GO TO 450
         ENDIF
         IF(ABS(THETA).LT.1.0)THEN
              IF((Y2DIST1.GT.-HAFTGTL).AND.(Y2DIST2.LT.HAFTGTL))THEN
                        Y23=0.0
                        GO TO 400
              ELSE
                        GO TO 450
              ENDIF
         ENDIF
         IF(ABS(THETA-90.0).LT.1)THEN
              PROD2=Y2DIST1-2.0*XDPRIM1
              IF((Y2DIST1.LT.HAFTGTL).AND.(PROD2.GT.-HAFTGTL))THEN
                        C4=C4+1
                        GO TO 100
              ELSE
                        GO TO 450
              ENDIF
         ENDIF
         Y23=Y2DIST1+((Y2DIST2-Y2DIST1)/(X2DIST2-X2DIST1))
```

```
     +    *(-HAFTCTW-X2DIST1)
400                         IF((Y23.GE.B).AND.(Y23.LE.HAFTCTL))THEN
                            C4=C4+1
                            GO TO 100
                            ENDIF
450   CONTINUE
                 C5=C5+1
100   CONTINUE
      PRINT*,
      PRINT*,'# TIMES NOT CUT DUE TO X-DIRECTION #1  ',C1
      PRINT*,
      PRINT*,'# TIMES NOT CUT DUE TO X-DIRECTION #2  ',C3
      PRINT*,
      PRINT*,'# TIMES CUT BY #1  ',C2
      PRINT*,
      PRINT*,'# TIMES CUT BY #2  ',C4
      PRINT*,
      PRINT*,'TOTAL CUTS ARE  ',C2+C4
      PRINT*,
      PRINT*,'# TIMES NOT CUT AT ALL  ',C5
      END
```

APPENDIX C

THREE-WAY AND FOUR-WAY ANOVAS

The SPSS program for the four-way ANOVA is listed on the next page. ANOVAs are listed in the following order: (1) four-way with interactions; (2) four-way without interactions; (3) three-way with interactions; and (4) three-way without interactions. The SPSS programs shows the ANOVAs excluding the variable UINT, the all other units interval, because the reconnaissance interval also varied by the same amount. By running SPSS with both of these factors, a singular matrix resulted because both these columns represent the same thing. Excluding this factor gave the ANOVA table. Tape 1 is a complete listing of all 256 simulation runs. The columns from left to right on tape 1 represent run number, policy, length, rate, reconnaissance units interval, all other unit intervals, and measure of effectiveness.

```
RUN NAME        MRD INTERDICTION ANALYSIS
PAGESIZE        50
FILE NAME       TAPE1(INTERDICTION RESULTS)
VARIABLE LIST   POLICY,LENGTH,RATE,RINT,UINT,VEHRAT
VAR LABELS      POLICY,INTERDICTION POLICY/
                LENGTH,CONVOY LENGTH/
                RATE,CONVOY RATE/
                RINT,RECON UNITS INTERVAL/
                UINT,ALL OTHER UNITS INTERVAL/
                VEHRAT,ARMORED VEHICLES PER HOUR/
RECODE          LENGTH(0=1) (0.1=2)
RECODE          RATE(25.0=1) (22.5=2)
RECODE          RINT(25.0=1) (22.5=2)
RECODE          UINT(4=1) (3.6=2)
N OF CASES      UNKNOWN
INPUT FORMAT    FIXED(4X,F4.0,5F8.2)
LIST CASES      CASES=20/VARIABLES=ALL
ANOVA           VEHRAT BY POLICY(1,4),LENGTH(1,2),RATE(1,2),
                RINT(1,2)
STATISTICS      ALL
READ INPUT DATA
FINISH
```

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * *

VEHRAT	ARMORED VEHICLES PER HOUR
BY POLICY	INTERDICTION POLICY
LENGTH	CONVOY LENGTH
RATE	CONVOY RATE
RINT	RECON UNITS INTERVAL

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	5031.203	6	838.534	88.481	.001
POLICY	3193.753	3	1064.584	112.334	.001
LENGTH	16.918	1	16.918	1.785	.183
RATE	1796.011	1	1796.011	189.514	.001
RINT	24.521	1	24.521	2.587	.109
2-WAY INTERACTIONS	25.855	12	2.155	.227	.997
POLICY LENGTH	1.327	3	.442	.047	.987
POLICY RATE	4.082	3	1.361	.144	.934
POLICY RINT	.329	3	.110	.012	.998
LENGTH RATE	.006	1	.006	.001	.980
LENGTH RINT	8.083	1	8.083	.853	.357
RATE RINT	12.028	1	12.028	1.269	.261
3-WAY INTERACTIONS	32.083	10	3.208	.339	.970
POLICY LENGTH RATE	.058	3	.019	.002	.999
POLICY LENGTH RINT	.117	3	.039	.004	.999
POLICY RATE RINT	.359	3	.120	.013	.998
LENGTH RATE RINT	31.549	1	31.549	3.329	.069
4-WAY INTERACTIONS	.522	3	.174	.018	.997
POLICY LENGTH RATE RINT	.522	3	.174	.018	.997
EXPLAINED	5089.664	31	164.183	17.324	.001
RESIDUAL	2122.837	224	9.477		
TOTAL	7212.501	255	28.284		

256 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * * *

VEHPAT   ARMORED VEHICLES PER HOUR
BY POLICY   INTERDICTION POLICY
LENGTH   CONVOY LENGTH
RATE   CONVOY RATE
RINT   RECON UNITS INTERVAL

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	5031.203	6	838.534	95.720	.001
POLICY	3193.753	3	1064.584	121.525	.001
LENGTH	16.918	1	16.918	1.931	.166
RATE	1796.011	1	1796.011	205.019	.001
RINT	24.521	1	24.521	2.799	.096
EXPLAINED	5031.203	6	838.534	95.720	.001
RESIDUAL	2181.298	249	8.760		
TOTAL	7212.501	255	28.284		

256 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

* * * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * *

VEHRAT ARMORED VEHICLES PER HOUR
BY POLICY INTERDICTION POLICY
RATE CONVOY RATE
RINT RECON UNITS INTERVAL

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	5014.285	5	1002.857	110.335	.001
POLICY	3193.753	3	1064.584	117.126	.001
RATE	1796.011	1	1796.011	197.597	.001
RINT	24.521	1	24.521	2.698	.102
2-WAY INTERACTIONS	16.439	7	2.348	.258	.969
POLICY RATE	4.082	3	1.361	.150	.930
POLICY RINT	.329	3	.110	.012	.998
RATE RINT	12.028	1	12.028	1.323	.251
3-WAY INTERACTIONS	.359	3	.120	.013	.998
POLICY RATE RINT	.359	3	.120	.013	.998
EXPLAINED	5031.083	15	335.406	36.901	.001
RESIDUAL	2181.418	240	9.089		
TOTAL	7212.501	255	28.284		

256 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

* * * * * * * * A N A L Y S I S   O F   V A R I A N C E * * * * * * * *

VEHRAT   ARMORED VEHICLES PER HOUR
BY POLICY   INTERDICTION POLICY
RATE   CONVOY RATE
RINT   RECON UNITS INTERVAL

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	5014.285	5	1002.857	114.054	.001
POLICY	3193.753	3	1064.584	121.074	.001
RATE	1796.011	1	1796.011	204.258	.001
RINT	24.521	1	24.521	2.789	.096
EXPLAINED	5014.285	5	1002.857	114.054	.001
RESIDUAL	2198.216	250	8.793		
TOTAL	7212.501	255	28.284		

256 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

IMRD INTERDICTION ANALYSIS   03/09/83   17.22.00.   PAGE   6

Tape 1

1	1	0.00	25.00	25.00	4.00	74.57
2	1	0.00	25.00	25.00	4.00	78.40
3	1	0.00	25.00	25.00	4.00	85.70
4	1	0.00	25.00	25.00	4.00	81.40
5	1	0.00	25.00	25.00	4.00	80.76
6	1	0.00	25.00	25.00	4.00	84.64
7	1	0.00	25.00	25.00	4.00	82.75
8	1	0.00	25.00	25.00	4.00	87.53
9	1	0.00	25.00	22.50	3.60	83.38
11	1	0.00	25.00	22.50	3.60	83.81
11	1	0.00	25.00	22.50	3.60	77.42
12	1	0.00	25.00	22.50	3.60	84.85
13	1	0.00	25.00	22.50	3.60	77.33
14	1	0.00	25.00	22.50	3.60	89.56
15	1	0.00	25.00	22.50	3.60	79.49
16	1	0.00	25.00	22.50	3.60	83.88
17	1	0.00	22.50	25.00	4.00	77.51
18	1	0.00	22.50	25.00	4.00	75.76
19	1	0.00	22.50	25.00	4.00	75.62
21	1	0.00	22.50	25.00	4.00	80.82
21	1	0.00	22.50	25.00	4.00	75.86
22	1	0.00	22.50	25.00	4.00	74.47
23	1	0.00	22.50	25.00	4.00	77.32
24	1	0.00	22.50	25.00	4.00	75.49
25	1	0.00	22.50	22.50	3.60	76.59
26	1	0.00	22.50	22.50	3.60	73.43
27	1	0.00	22.50	22.50	3.60	81.20
28	1	0.00	22.50	22.50	3.60	72.31
29	1	0.00	22.50	22.50	3.60	73.95
31	1	0.00	22.50	22.50	3.60	77.09
31	1	0.00	22.50	22.50	3.60	74.94
32	1	0.00	22.50	22.50	3.60	82.32
33	1	.10	25.00	25.00	4.00	79.99
34	1	.10	25.00	25.00	4.00	80.69
35	1	.10	25.00	25.00	4.00	75.87
36	1	.10	25.00	25.00	4.00	85.84
37	1	.10	25.00	25.00	4.00	86.54
38	1	.10	25.00	25.00	4.00	86.95
39	1	.10	25.00	25.00	4.00	82.59
41	1	.10	25.00	25.00	4.00	86.65
41	1	.10	25.00	22.50	3.60	81.28
42	1	.10	25.00	22.50	3.60	80.52
43	1	.10	25.00	22.50	3.60	80.97
44	1	.10	25.00	22.50	3.60	80.54
45	1	.10	25.00	22.50	3.60	82.97
46	1	.10	25.00	22.50	3.60	86.06
47	1	.10	25.00	22.50	3.60	85.64
48	1	.10	25.00	22.50	3.60	84.18
49	1	.10	22.50	25.00	4.00	75.64
51	1	.10	22.50	25.00	4.00	74.89

51	1	.10	22.50	25.00	4.00	73.34
52	1	.10	22.50	25.00	4.00	80.77
53	1	.10	22.50	25.00	4.00	78.34
54	1	.10	22.50	25.00	4.00	76.52
55	1	.10	22.50	25.00	4.00	73.87
56	1	.10	22.50	25.00	4.00	75.31
57	1	.10	22.50	22.50	3.60	77.42
58	1	.10	22.50	22.50	3.60	83.50
59	1	.10	22.50	22.50	3.60	79.88
60	1	.10	22.50	22.50	3.60	77.61
61	1	.10	22.50	22.50	3.60	74.46
62	1	.10	22.50	22.50	3.60	78.09
63	1	.10	22.50	22.50	3.60	79.08
64	1	.10	22.50	22.50	3.60	76.82
1	2	0.00	25.00	25.00	4.00	68.06
2	2	0.00	25.00	25.00	4.00	71.25
3	2	0.00	25.00	25.00	4.00	76.98
4	2	0.00	25.00	25.00	4.00	74.55
5	2	0.00	25.00	25.00	4.00	74.15
6	2	0.00	25.00	25.00	4.00	77.60
7	2	0.00	25.00	25.00	4.00	75.19
8	2	0.00	25.00	25.00	4.00	79.68
9	2	0.00	25.00	22.50	3.60	76.05
10	2	0.00	25.00	22.50	3.60	76.26
11	2	0.00	25.00	22.50	3.60	70.37
12	2	0.00	25.00	22.50	3.60	77.53
13	2	0.00	25.00	22.50	3.60	70.85
14	2	0.00	25.00	22.50	3.60	81.46
15	2	0.00	25.00	22.50	3.60	72.10
16	2	0.00	25.00	22.50	3.60	76.04
17	2	0.00	22.50	25.00	4.00	71.30
18	2	0.00	22.50	25.00	4.00	69.31
19	2	0.00	22.50	25.00	4.00	68.74
20	2	0.00	22.50	25.00	4.00	73.24
21	2	0.00	22.50	25.00	4.00	69.13
22	2	0.00	22.50	25.00	4.00	68.28
23	2	0.00	22.50	25.00	4.00	70.46
24	2	0.00	22.50	25.00	4.00	68.64
25	2	0.00	22.50	22.50	3.60	69.70
26	2	0.00	22.50	22.50	3.60	67.32
27	2	0.00	22.50	22.50	3.60	74.76
28	2	0.00	22.50	22.50	3.60	65.44
29	2	0.00	22.50	22.50	3.60	66.62
30	2	0.00	22.50	22.50	3.60	69.77
31	2	0.00	22.50	22.50	3.60	68.00
32	2	0.00	22.50	22.50	3.60	76.1[illegible]
33	2	.10	25.00	25.00	4.00	73.07
34	2	.10	25.00	25.00	4.00	72.79
35	2	.10	25.00	25.00	4.00	68.71
36	2	.10	25.00	25.00	4.00	78.62

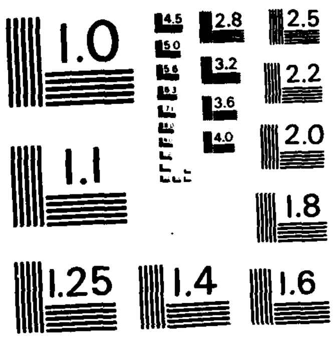
37	2	.10	25.00	25.00	4.00	77.83
38	2	.10	25.00	25.00	4.00	79.71
39	2	.10	25.00	25.00	4.00	74.78
40	2	.10	25.00	25.00	4.00	78.43
41	2	.10	25.00	22.50	3.60	73.62
42	2	.10	25.00	22.50	3.60	73.23
43	2	.10	25.00	22.50	3.60	74.11
44	2	.10	25.00	22.50	3.60	72.84
45	2	.10	25.00	22.50	3.60	76.28
46	2	.10	25.00	22.50	3.60	77.42
47	2	.10	25.00	22.50	3.60	77.99
48	2	.10	25.00	22.50	3.60	76.71
49	2	.10	22.50	25.00	4.00	68.41
50	2	.10	22.50	25.00	4.00	68.20
51	2	.10	22.50	25.00	4.00	67.14
52	2	.10	22.50	25.00	4.00	73.23
53	2	.10	22.50	25.00	4.00	71.28
54	2	.10	22.50	25.00	4.00	70.07
55	2	.10	22.50	25.00	4.00	67.67
56	2	.10	22.50	25.00	4.00	68.56
57	2	.10	22.50	22.50	3.60	70.31
58	2	.10	22.50	22.50	3.60	76.47
59	2	.10	22.50	22.50	3.60	73.32
60	2	.10	22.50	22.50	3.60	70.56
61	2	.10	22.50	22.50	3.60	67.92
62	2	.10	22.50	22.50	3.60	70.80
63	2	.10	22.50	22.50	3.60	71.87
64	2	.10	22.50	22.50	3.60	70.18
1	3	0.00	25.00	25.00	4.00	67.69
2	3	0.00	25.00	25.00	4.00	70.13
3	3	0.00	25.00	25.00	4.00	77.34
4	3	0.00	25.00	25.00	4.00	73.60
5	3	0.00	25.00	25.00	4.00	73.22
6	3	0.00	25.00	25.00	4.00	76.53
7	3	0.00	25.00	25.00	4.00	74.04
8	3	0.00	25.00	25.00	4.00	79.51
9	3	0.00	25.00	22.50	3.60	76.16
10	3	0.00	25.00	22.50	3.60	74.95
11	3	0.00	25.00	22.50	3.60	69.66
12	3	0.00	25.00	22.50	3.60	76.91
13	3	0.00	25.00	22.50	3.60	70.47
14	3	0.00	25.00	22.50	3.60	81.20
15	3	0.00	25.00	22.50	3.60	70.95
16	3	0.00	25.00	22.50	3.60	76.19
17	3	0.00	22.50	25.00	4.00	68.95
18	3	0.00	22.50	25.00	4.00	67.94
19	3	0.00	22.50	25.00	4.00	67.93
20	3	0.00	22.50	25.00	4.00	72.00
21	3	0.00	22.50	25.00	4.00	68.02
22	3	0.00	22.50	25.00	4.00	68.03

23	3	0.00	22.50	25.00	4.00	70.35
24	3	0.00	22.50	25.00	4.00	68.20
25	3	0.00	22.50	22.50	3.60	69.61
26	3	0.00	22.50	22.50	3.60	66.22
27	3	0.00	22.50	22.50	3.60	74.57
28	3	0.00	22.50	22.50	3.60	65.30
29	3	0.00	22.50	22.50	3.60	66.08
30	3	0.00	22.50	22.50	3.60	69.14
31	3	0.00	22.50	22.50	3.60	67.36
32	3	0.00	22.50	22.50	3.60	73.99
33	3	.10	25.00	25.00	4.00	72.48
34	3	.10	25.00	25.00	4.00	71.75
35	3	.10	25.00	25.00	4.00	68.60
36	3	.10	25.00	25.00	4.00	77.43
37	3	.10	25.00	25.00	4.00	77.61
38	3	.10	25.00	25.00	4.00	78.78
39	3	.10	25.00	25.00	4.00	74.45
40	3	.10	25.00	25.00	4.00	78.12
41	3	.10	25.00	22.50	3.60	73.10
42	3	.10	25.00	22.50	3.60	73.32
43	3	.10	25.00	22.50	3.60	73.06
44	3	.10	25.00	22.50	3.60	72.16
45	3	.10	25.00	22.50	3.60	73.89
46	3	.10	25.00	22.50	3.60	77.11
47	3	.10	25.00	22.50	3.60	78.29
48	3	.10	25.00	22.50	3.60	76.65
49	3	.10	22.50	25.00	4.00	67.20
50	3	.10	22.50	25.00	4.00	67.38
51	3	.10	22.50	25.00	4.00	66.33
52	3	.10	22.50	25.00	4.00	72.81
53	3	.10	22.50	25.00	4.00	69.57
54	3	.10	22.50	25.00	4.00	69.12
55	3	.10	22.50	25.00	4.00	67.02
56	3	.10	22.50	25.00	4.00	67.88
57	3	.10	22.50	22.50	3.60	68.75
58	3	.10	22.50	22.50	3.60	75.29
59	3	.10	22.50	22.50	3.60	71.84
60	3	.10	22.50	22.50	3.60	70.10
61	3	.10	22.50	22.50	3.60	67.29
62	3	.10	22.50	22.50	3.60	71.32
63	3	.10	22.50	22.50	3.60	70.02
64	3	.10	22.50	22.50	3.60	70.00
1	4	0.00	25.00	25.00	4.00	66.46
2	4	0.00	25.00	25.00	4.00	70.02
3	4	0.00	25.00	25.00	4.00	73.92
4	4	0.00	25.00	25.00	4.00	72.37
5	4	0.00	25.00	25.00	4.00	72.33
6	4	0.00	25.00	25.00	4.00	76.30
7	4	0.00	25.00	25.00	4.00	72.34
8	4	0.00	25.00	25.00	4.00	78.30

9	4	0.00	25.00	22.50	3.60	75.24
10	4	0.00	25.00	22.50	3.60	73.11
11	4	0.00	25.00	22.50	3.60	69.45
12	4	0.00	25.00	22.50	3.60	75.74
13	4	0.00	25.00	22.50	3.60	68.98
14	4	0.00	25.00	22.50	3.60	70.48
15	4	0.00	25.00	22.50	3.60	71.50
16	4	0.00	25.00	22.50	3.60	73.88
17	4	0.00	22.50	25.00	4.00	67.66
18	4	0.00	22.50	25.00	4.00	67.52
19	4	0.00	22.50	25.00	4.00	67.20
20	4	0.00	22.50	25.00	4.00	71.66
21	4	0.00	22.50	25.00	4.00	67.29
22	4	0.00	22.50	25.00	4.00	66.49
23	4	0.00	22.50	25.00	4.00	68.97
24	4	0.00	22.50	25.00	4.00	66.53
25	4	0.00	22.50	22.50	3.60	69.29
26	4	0.00	22.50	22.50	3.60	65.72
27	4	0.00	22.50	22.50	3.60	71.77
28	4	0.00	22.50	22.50	3.60	64.90
29	4	0.00	22.50	22.50	3.60	65.17
30	4	0.00	22.50	22.50	3.60	66.91
31	4	0.00	22.50	22.50	3.60	66.74
32	4	0.00	22.50	22.50	3.60	74.10
33	4	.10	25.00	25.00	4.00	71.04
34	4	.10	25.00	25.00	4.00	70.42
35	4	.10	25.00	25.00	4.00	67.76
36	4	.10	25.00	25.00	4.00	77.19
37	4	.10	25.00	25.00	4.00	75.23
38	4	.10	25.00	25.00	4.00	76.86
39	4	.10	25.00	25.00	4.00	72.05
40	4	.10	25.00	25.00	4.00	76.33
41	4	.10	25.00	22.50	3.60	72.99
42	4	.10	25.00	22.50	3.60	70.98
43	4	.10	25.00	22.50	3.60	71.17
44	4	.10	25.00	22.50	3.60	70.84
45	4	.10	25.00	22.50	3.60	74.46
46	4	.10	25.00	22.50	3.60	75.58
47	4	.10	25.00	22.50	3.60	76.87
48	4	.10	25.00	22.50	3.60	75.27
49	4	.10	22.50	25.00	4.00	65.84
50	4	.10	22.50	25.00	4.00	65.73
51	4	.10	22.50	25.00	4.00	66.03
52	4	.10	22.50	25.00	4.00	71.03
53	4	.10	22.50	25.00	4.00	68.92
54	4	.10	22.50	25.00	4.00	67.23
55	4	.10	22.50	25.00	4.00	66.20
56	4	.10	22.50	25.00	4.00	67.47
57	4	.10	22.50	22.50	3.60	67.47
58	4	.10	22.50	22.50	3.60	74.25

AD-A139 495 STOPEM: A SIMULATION INTERDICTION MODEL OF A MOTORIZED RIFLE DIVISION(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING 3/3

UNCLASSIFIED G A FULTON MAR 83 AFIT/GST/OS/83M-2 F/G 15/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

59	4	.10	22.50	22.50	3.60	70.85
60	4	.10	22.50	22.50	3.60	67.96
61	4	.10	22.50	22.50	3.60	64.84
62	4	.10	22.50	22.50	3.60	69.93
63	4	.10	22.50	22.50	3.60	69.58
64	4	.10	22.50	22.50	3.60	69.74

APPENDIX D

TESTS OF STATISTICAL DISTRIBUTIONS

SPSS tests for uniform distribution are presented in this Appendix. The uniform distribution used in SORTIE and MISSILE was tested using a Kolmogorov-Smirnov (K-S) test. The SPSS program for this analysis precedes the results. An alpha of 0.05 was used in testing a sample of 576 random variates. A sample of 100 of these 576 numbers, tape 12, is shown following the SPSS results

Distribution of SORTIE and MISSILE

The K-S test done tested the following:

H_o: The 576 random variates came from a Uniform (0,1) distribution.

H_1: The 576 random variates did not come from a Uniform (0,1) distribution.

$$D_{crit} = D_{.05,576} = 0.057$$

The underlined portion of the SPSS printout shows that the computed value was 0.0253.

$$0.0253 < 0.057$$

$|D|_{max} < D_{crit}$ for alpha equals to 0.05.

Therefore, the null hypothesis cannot be rejected.

```
RUN NAME          RANDOM UNIFORM STREAM(THESIS)
PAGESIZE          50
FILE NAME         TAPE12
VARIABLES LIST    NNRUN,RNUMB
VAR LABELS        NNRUN,SIMULATION RUN/RNUMB,RANDOM NUMBER GENERATED
N OF CASES        UNKNOWN
INPUT FORMAT      FIXED(F4.0,F8.2)
LIST CASES        CASES=50/VARIABLES=ALL
NPAR TESTS        K-S(UNIFORM 0,1)=RNUMB/
                  RUNS(0.5)=RNUMB/
OPTIONS           5
STATISTICS        ALL
READ INPUT DATA
FINISH
*
*
*
*
1RANDOM UNIFORM STREAM(THESIS)                02/26/83  23.17.21.    PAGE     5

 FILE - TAPE11   (CREATED -  02/26/83)

 VARIABLE             N        MEAN      STD DEV     MINIMUM     MAXIMUM

 RNUMB              576        .494        .287          0        1.000
1RANDOM UNIFORM STREAM(THESIS)                02/26/83  23.17.21.    PAGE     6

 FILE - TAPE11   (CREATED -  02/26/83)

 - - - - - KOLMOGOROV - SMIRNOV GOODNESS OF FIT TEST

     RNUMB       RANDOM NUMBER GENERATED

 TEST DIST. - UNIFORM (RANGE =             0 TO        1.0000)

           CASES      MAX(ABS DIFF)     MAX(+ DIFF)     MAX(- DIFF)
             576          .0253            .0253          -.0165
      ----------------------------------------------------------------

           K-S Z         2-TAILED P
            .607            .855
```

Tape 12

1	.51
1	.16
1	.63
1	.87
1	.96
1	.41
1	.36
1	.95
1	.93
1	.86
1	.98
1	.08
2	.30
2	.42
2	.64
2	.65
2	.83
2	.56
2	.72
2	.79
2	.88
2	.64
2	.08
2	.30
3	.40
3	.55
3	.52
3	.28
3	.94
3	.16
3	.01
3	.38
3	.15
3	.88
3	.98
3	.01
4	.47
4	.84
4	.11
4	.79
4	.27
4	.80
4	.32
4	.74
4	.12
4	.34
4	.93
4	.69
5	.21
5	.42
5	.15
5	.56
5	.60
5	.58
5	.71
5	.57
5	.09
5	.44
5	.18
5	.47
6	.51
6	.55
6	.47
6	.24
6	.31
6	.35
6	.49
6	.24
6	.19
6	.06
6	.25
6	.74
7	.28
7	.44
7	.49
7	.05
7	.37
7	.58
7	.77
7	.37
7	.40
7	.88
7	.61
7	.90
8	.61
8	.95
8	.19
8	.41
8	.50
8	.89
8	.97
8	.49
8	.23
8	.22
8	.16
8	.41
9	.44
9	.32
9	.83
9	.23

APPENDIX E

VERIFICATION DATA

The following outputs from the model demonstrate the model is working as intended. The first output shows the information used in developing the measure of effectiveness. Tape 18 shows no interdiction result on total number of armored vehicles, the finish time for the last entity on each route, and the MRD average finish time. This tape shows a constant number of armored vehicles, but varying finish times. Tape 21, representing Policy four, shows the variation of both time and vehicles. The last two tapes, tapes 14 and 17, show the effect on order of finish and time of finish for no interdiction and interdiction. Tape 14 represents no interdiction and 17 is interdiction. The columns on tapes 14 and 17 from left to right represent route number, run number, policy, number of armored vehicles, unit number, and finish time. Thus, the model is maintaining convoy order as originally intended. The last three pages in this appendix represent selected print statements included at strategic portions of the model to verify the interdiction subroutines. These show the sortie and missile attacks results. All global variables are as explained at start of SLAM coded portion of network, Appendix A. The 'AT' represents shorthand for attribute. The printed values show that the model is working as intended.

```
   1
FINISH TIMES        9.70     9.40     8.42
AVERAGE TIME        9.17
ARMORED VEHICLES      684.00
   2
FINISH TIMES        8.92     9.22     8.03
AVERAGE TIME        8.72
ARMORED VEHICLES      684.00
   3
FINISH TIMES        8.20     9.24     6.50
AVERAGE TIME        7.98
ARMORED VEHICLES      684.00
   4
FINISH TIMES        7.42     8.73     9.06
AVERAGE TIME        8.40
ARMORED VEHICLES      684.00
   5
FINISH TIMES        9.45     9.02     6.94
AVERAGE TIME        8.47
ARMORED VEHICLES      684.00
   6
FINISH TIMES        8.46     9.02     6.77
AVERAGE TIME        8.08
ARMORED VEHICLES      684.00
   7
FINISH TIMES        7.67     9.24     7.88
AVERAGE TIME        8.27
ARMORED VEHICLES      684.00
   8
FINISH TIMES        8.16     7.97     7.30
AVERAGE TIME        7.81
ARMORED VEHICLES      684.00
   9
FINISH TIMES        8.28     9.29     7.05
AVERAGE TIME        8.20
ARMORED VEHICLES      684.00
  10
FINISH TIMES        9.26     8.50     6.73
AVERAGE TIME        8.16
ARMORED VEHICLES      684.00
  11
FINISH TIMES        9.36     8.78     8.37
AVERAGE TIME        8.84
ARMORED VEHICLES      684.00
  12
FINISH TIMES        9.19     8.58     6.41
AVERAGE TIME        8.06
ARMORED VEHICLES      684.00
```

```
    1
FINISH TIMES        10.01     10.26      8.94
AVERAGE TIME         9.74
ARMORED VEHICLES      647.00
    2
FINISH TIMES         9.21     10.09      8.55
AVERAGE TIME         9.28
ARMORED VEHICLES      650.00
    3
FINISH TIMES         8.43     10.10      6.92
AVERAGE TIME         8.48
ARMORED VEHICLES      627.00
    4
FINISH TIMES         7.64      9.56      9.62
AVERAGE TIME         8.94
ARMORED VEHICLES      647.00
    5
FINISH TIMES         9.71      9.85      7.40
AVERAGE TIME         8.99
ARMORED VEHICLES      650.00
    6
FINISH TIMES         8.71      9.86      7.19
AVERAGE TIME         8.58
ARMORED VEHICLES      655.00
    7
FINISH TIMES         7.87     10.14      8.37
AVERAGE TIME         8.79
ARMORED VEHICLES      636.00
    8
FINISH TIMES         8.41      8.73      7.76
AVERAGE TIME         8.30
ARMORED VEHICLES      650.00
    9
FINISH TIMES         8.51     10.15      7.49


AVERAGE TIME         8.72
ARMORED VEHICLES      656.00
   10
FINISH TIMES         9.55      9.29      7.14
AVERAGE TIME         8.66
ARMORED VEHICLES      633.00
   11
FINISH TIMES         9.62      9.60      8.90
AVERAGE TIME         9.37
ARMORED VEHICLES      651.00
   12
FINISH TIMES         9.46      9.37      6.83
AVERAGE TIME         8.56
ARMORED VEHICLES      648.00
```

Tape 14

3	1	0	39.00	32.00	4.22
2	1	0	57.00	16.00	4.66
1	1	0	57.00	1.00	4.95
3	1	0	6.00	33.00	4.13
3	1	0	33.00	34.00	4.17
2	1	0	5.00	17.00	4.56
3	1	0	23.00	35.00	4.15
2	1	0	28.00	18.00	4.57
1	1	0	5.00	2.00	4.81
3	1	0	15.00	36.00	4.28
2	1	0	33.00	19.00	4.57
1	1	0	28.00	3.00	4.83
3	1	0	5.00	37.00	4.16
2	1	0	30.00	20.00	4.58
1	1	0	33.00	4.00	4.84
3	1	0	0.00	38.00	4.13
1	1	0	30.00	5.00	4.83
2	1	0	7.00	21.00	4.67
3	1	0	57.00	39.00	4.23
2	1	0	0.00	22.00	4.61
1	1	0	7.00	6.00	4.96
3	1	0	5.00	40.00	4.15
2	1	0	0.00	23.00	4.60
1	1	0	51.00	7.00	4.85
3	1	0	28.00	41.00	4.17
2	1	0	0.00	24.00	4.61
1	1	0	5.00	8.00	4.82
3	1	0	33.00	42.00	4.18
1	1	0	0.00	9.00	4.79
2	1	0	22.00	25.00	4.70
3	1	0	23.00	43.00	4.20
1	1	0	0.00	10.00	4.85
2	1	0	0.00	26.00	4.61
3	1	0	14.00	44.00	4.33
1	1	0	0.00	11.00	4.88
2	1	0	0.00	27.00	4.64
1	1	0	0.00	12.00	4.81
2	1	0	0.00	28.00	4.59
1	1	0	0.00	13.00	4.87
2	1	0	5.00	29.00	4.61
2	1	0	0.00	30.00	4.54
1	1	0	0.00	14.00	4.84
2	1	0	0.00	31.00	4.56
1	1	0	0.00	15.00	5.14

Tape 17

3	1	1	26.00	32.00	4.46
3	1	1	6.00	33.00	4.66
1	1	1	5.00	2.00	4.83
3	1	1	33.00	34.00	4.69
1	1	1	28.00	3.00	4.84
2	1	1	5.00	17.00	5.11
3	1	1	23.00	35.00	4.67
2	1	1	28.00	18.00	5.12
1	1	1	33.00	4.00	4.85
3	1	1	15.00	36.00	4.80
2	1	1	33.00	19.00	5.12
1	1	1	30.00	5.00	4.84
3	1	1	5.00	37.00	4.69
2	1	1	30.00	20.00	5.13
3	1	1	0.00	38.00	4.66
1	1	1	7.00	6.00	4.97
2	1	1	7.00	21.00	5.22
1	1	1	51.00	7.00	4.86
3	1	1	57.00	39.00	4.75
2	1	1	0.00	22.00	5.16
1	1	1	5.00	8.00	4.83
3	1	1	5.00	40.00	4.67
1	1	1	0.00	9.00	4.80
2	1	1	0.00	23.00	5.15
3	1	1	28.00	41.00	4.69
1	1	1	0.00	10.00	4.86
2	1	1	0.00	24.00	5.16
3	1	1	33.00	42.00	4.71
1	1	1	0.00	11.00	4.89
3	1	1	23.00	43.00	4.72
2	1	1	22.00	25.00	5.25
1	1	1	0.00	12.00	4.82
2	1	1	0.00	26.00	5.16
1	1	1	0.00	13.00	4.89
3	1	1	14.00	44.00	4.85
2	1	1	0.00	27.00	5.19
1	1	1	0.00	14.00	4.85
2	1	1	0.00	28.00	5.14
2	1	1	5.00	29.00	5.16
1	1	1	0.00	15.00	5.15
2	1	1	0.00	30.00	5.09
2	1	1	0.00	31.00	5.02
1	1	1	47.00	1.00	10.01
2	1	1	43.00	16.00	10.26

```
PASS   .5101872978055
ROAD IS NOT CUT PASS #    1
DTIMER   14.25276453119
XX(10)   1.

XX(9)   0.

PASS   .159273323972
ROAD IS CUT PASS #   2
DTIME   35.09184583312
XX(10)   1.

XX(9)   1.
NUM PLANES   28.
SORTIE--UNIT #   32.
AT3   37.
AT8   2.692734177166
AT16   3.050528190703
DTMIS1   19.37659403687
DTMIS2   35.53440716602
DTMIS3   45.6406214843

VEHICLE INTERVAL(FEET)   185.3845273524

SHOT   .6313601292511

SHOT   .8707965090511

SHOT   .3613165051903
NUMKIL   11
DTMIS3   .7606770247384
MISSILE--UNIT#   32.
VEHICLES   26.
NEW TIME   3.811205215441
NEW LENGTH   2.205234177166
```

```
PASS   .9569695253164
ROAD IS NOT CUT PASS #   1
DTIMER   11.64824734468
XX(10)  1.

XX(9)  0.

PASS   .4122673628989
ROAD IS NOT CUT PASS #   2
DTIMER   11.64824734468
XX(10)  1.

XX(9)  0.
NUM PLANES  26.
SORTIE--UNIT #  1.
AT3  55.
AT8  4.051337346887
AT16  3.120135337595
DTMIS1  20.45171644504
DTMIS2  32.117626707
DTMIS3  37.18601648972

VEHICLE INTERVAL(FEET)  144.2942553959

SHOT  .9546373293371

SHOT  .9777969176691

SHOT  .07643264419774
NUMKIL  8
DTMIS2  .535209377845
MISSILE--UNIT#  1.
VEHICLES  47.
NEW TIME  3.655429115955
NEW LENGTH  3.676337346887
```

```
PASS   .92755872472
ROAD IS NOT CUT PASS #    1
DTIMEP   14.5790094986
XX(10)   1.

XX(9)   0.

PASS   .8565646735418
ROAD IS NOT CUT PASS #    2
DTIMEP   14.5790094986
XX(10)   1.

XX(9)   0.
NUM PLANES   24.
SORTIE--UNIT #   16.
AT3   55.
AT8   3.577466358608
AT16   3.375682894566
DTMIS1   19.47190886159
DTMIS2   31.67459602293
DTMIS3   38.1788130497

VEHICLE INTERVAL(FEET)   126.4241997243

SHOT   .6436632225973

SHOT   .6541157626746

SHOT   .7219237384348
NUMKIL   12
DTMIS3   .6363135508284
MISSILE--UNIT#   16.
VEHICLES   43.
NEW TIME   4.011996445394
NEW LENGTH   3.052466358608
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Vita

George A. Fulton was born on 6 October 1950 in Corpus Christi, Texas. He graduated from Calallen High School, Corpus Christi, Texas, in May 1969, and then attended the United States Military Academy. He was awarded a Bachelor of Science degree and was commissioned in the Infantry in June 1973. Following completion of Infantry Officer Basic Course and Ranger School at Fort Benning, Georgia, he served with the 1st Battalion (M) 10th Infantry at Fort Carson, Colorado. Upon completion of the Advanced Infantry Course at Fort Benning in 1978, he was assigned to Germany where he served as staff officer and later as Company Commander for Headquarters Company, ACE Mobile Force Land (AMFL). Upon his return from Germany, he was assigned in June 1981 to the School of Engineering, Air Force Institute of Technology.

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